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ORIGINAL ARTICLES.

I.—Sand-blast of the Shore and its Erosive Effect on Wood.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

(PLATE X.)

THE effect of the natural sand-blast of the desert in eroding soft and hard rock has long been known, and attracted much attention, but I cannot call to mind any account of the effect of blowing sand impinging upon wood.

From seven to eight years ago a boat-house was built by the Blundellsands Sailing Club on the sandhills at the Altmouth, about 8 or 9 feet above high-water mark of spring tides. Afterwards, for better access thereto, a sloped road was built up of timbers from the shore level, leading to a level gangway about 10 feet above the shore, also made of timbers. This gangway was 6 feet wide and 12 feet long, with close-boarded sides about 2 feet high formed of roughly sawn pine boards and split-oak staves. This formed a trough having a direction about west-north-west, and really became a wind-gap.

The effect of the sand-blast on the southern face of the northern side has been most striking and curious. The boat-house has just been taken down and re-erected at a lower level, and my sons, members of the club, have brought me a sample of the pine boarding and of the split-oak staves from the north side of the old gangway. These are reproduced in the Plate from photographs by Hartley Bros., Waterloo. The general effect of the sand-blast has been to remove from one-eighth to three-sixteenths of an inch of wood over a large part of the surface of the pine board (Pl. X, Fig. 1), and to develop the structure of the wood in a remarkable manner. The grain being very irregular, the differential effect of the impinging sand-grains on the harder and softer portions is most instructive.

It will be observed that the large hard knot stands out above the general surface of the wood, and that the grain around the knot is picked out in a surprising manner. The knot itself is carved and polished. Perhaps the most instructive feature is the effect of the

three nails in preserving the wood in the rear or *lee* of the nails, the course of the sand-blast having been from left to right. These are wire nails that fastened the board horizontally to the upright posts. The heads of these nails mark the original sawn surface of the board, and indicate well the amount of the general denudation the board has undergone. In the year 1875 I contributed a short article to this Magazine on "Wind Denudation," describing little ridges of sand on the shore left on the leeside of fragments of shells, or sometimes whole shells, which have protected the sand from the general denudation which always takes place in the upper moist part of the shore during a strong breeze. These little ridges I ventured to call 'eolites.' The wood ridges left in the rear of the nail heads are the counterparts of these eolites, but they are actually carved out of the board by the mechanical battering of the sand-grains, whereas the eolites are due to the wind first drying the surface of the sand and then blowing the grains away, except where protected by the shell fragments.

Another interesting feature is the rope-like appearance caused by the truncation of bundles of fibres, shown by the minute transverse markings on the photograph. This happens only where the grain is not parallel to the surface of the wood.

The effect on the oak staves is equally characteristic. Here, in consequence of the regularity and parallelism of the grain, grooves have been cut by the sand with the precision of a planing machine (Fig. 2).

Since the preceding was written another pine board has been brought to me. It measures 2 ft. 6 in. × 6¾ in. The timber is rather harder than in the one already described, and the grain more regular. The sand has cut grooves of segmental section from three-sixteenths to half an inch wide, deeply undercut on one side, the ridges between the grooves being like a knife edge. There are hardly any of the transverse markings to be seen, the grain being parallel to the surface, and the whole has a smooth polished surface to the touch.

It is interesting to find that the continual attrition of these quartzose sand-grains, many of them much rounded, in time cuts deeply into the wood and develops the structure by differential action on the harder and softer parts it operates upon, and also polishes the surface. The time the wood has been exposed to the blast is about seven years. What the velocity of the grains was in a high wind I have no means of judging, but no doubt the air currents were intensified in this wind-gap, and it must not be taken as representative of the whole shore.

EXPLANATION OF PLATE X.

Fig. 1.—Portion of a pine board, 1 ft. 1 in. × 5 in., eroded by sand-blast of the shore.
Fig. 2.—Portion of a split-oak stave, 5½ in. × 2½ in., ,, ,, ,,

II.—Note on Graptolites from Peru.

By E. T. Newton, F.R.S., F.G.S., etc.

MR. HERBERT J. JESSOP, who has recently returned from a journey in Eastern Peru, kindly placed in my hands, for examination, some specimens of graptolites which he had obtained on the River Macho, one of the tributaries of the Inambari, near the celebrated mountain Capac Orco, or Monte Bello, in the province of Carabaya, Peru (lat. 13° 40′ S.; long. 70° 10′ W.). The locality is situated on the north-east of the main watershed, and the rivers flow eventually into the Amazon. The difficulties of travelling make it likely that a long time will elapse before other specimens are forthcoming from this locality; it seems desirable, therefore, that some account of these should be published.

Fig. 1.

Fig. 2.

Fig. 1.—Fragment of black shale with *Diplograptus*; natural size; Carabaya, Peru. From a photograph kindly taken by Mr. A. Strahan.

Fig. 2.—Specimen marked on Fig. 1; enlarged 1½ times. The virgula has been added from another example.

Mr. Jessop tells me that the pieces of black shale containing the graptolites were portions of a mass of rock about two feet square and one foot thick, which was not found in place, but loose upon the ground; its unrolled and unweathered condition convincing him that it could not have travelled far from the parent bed. Similar shaly rocks are in place near by, but he was prevented from making a careful exploration. The specimens obtained seemed to him sufficiently interesting to be brought home, notwithstanding that everything had to be carried by the men for many miles, the place being inaccessible for horses or mules.

The whole mass of shale seems to be full of these graptolites, for, wherever split open, many white examples are displayed upon the surface of the black shale (Fig. 1), all of which are referable to the genus *Diplograptus*, and although differing somewhat in width they are so similar in other respects that they can hardly represent more than one species. The longest and most perfect specimen (Fig. 2) does not exceed 25 mm. in length and 3 mm. in width at the widest part; but this example has no projecting virgula, such as is seen on other specimens extending perhaps 4 or 5 mm. beyond the thecæ. Some examples are a little narrower, while one is as much as 5 mm. wide. The polypary has a small radicle and two cornua at its proximal end, and thence increases somewhat rapidly in width for about a third of its length and then decreases slightly and very gradually to the distal extremity, from which, in several specimens, a virgula extends. In one instance the virgula may be traced throughout the length of the polypary. The thecæ diverge from each side of the axis at an angle of rather less than 45°; the apertural margin is nearly at right angles with the axis, and the outer free margin is in most cases slightly convex; but there is some variation in all these particulars, even in the same polypary. There are 11–13 thecæ in 10 mm. These Peruvian Diplograptids very closely resemble the *D. truncatus* of Lapworth,[1] and Professor Lapworth, who saw the specimens for a few minutes, was good enough to point out this near resemblance. The small differences which may be noticed, namely, the distinct virgula, the somewhat smaller thecæ, and the less oblique apertural margin, as well apparently as the shorter polypary, probably indicate that specific difference which one is led to expect from the widely separated habitats of the two forms; at the same time one hesitates to give them a new name, and would prefer to record them as *Diplograptus*, cf. *truncatus*, Lapw., and as probably of Bala age.

Little is known of the geology of the immediate area from which Mr. Jessop obtained his graptolites; but David Forbes, in his paper on "The Geology of Bolivia and Southern Peru,"[2] not only gives a large area of Silurian rocks extending from the south-east to the north-west border of his map, which is perhaps within a hundred miles of Monte Bello, but says that these Silurian strata extend as far as Cuzco, and this would be as far north and well to the west of the district now in question. David Forbes does not appear to have visited this area himself, and the fossils collected further south, which were described by J. W. Salter, were said to indicate beds of Upper Silurian age, and probably Lower Silurian also. The fossils doubtfully referred to the Lower Silurian certainly left much to be desired. No graptolites were found, and consequently a most important guide to the age of these old rocks was wanting.

D'Orbigny, during his travels in Bolivia,[3] found certain graptolites at Tacopaya, near the Rio Grand (lat. 19° S.; long. 63° 40′ W.),

[1] Proc. Belfast Nat. Field Club, ser. II, vol. i, pt. 4, Appendix, p. 133, 1876–7.
[2] Quart. Journ. Geol. Soc., vol. xvii (1861), p. 53.
[3] "Voyage dans l'Amérique Méridionale": Palæont., vol. iv (1842), p. 23.

which he named *Graptolites dentatus*; but finding that they had two branches, united them with *Graptolites* (now *Didymograptus*) *Murchisoni*; *Grap. foliaceus* was likewise included, and as this is a Diplograptid there must be much doubt as to the specific identity of his Bolivian forms, although the published figures leave little doubt as to their belonging to the genus *Didymograptus*, and consequently point to beds of Llandeilo or Arenig age; that is, if we are right in using the zonal distribution of Old World Graptolites as an index for those of Central South America.

Both Cambrian and Silurian fossils have been described from Northern Argentina (lat. 23½° and 25° S.) by Professor Kayser,[1] and from Portezuelo many examples of a *Didymograptus* are noticed which he thinks may be the same form as that brought from Bolivia by D'Orbigny, thus again pointing to Llandeilo or Arenig rocks a long way to the south-east, and confirming the occurrence of strata of that age in the central part of South America.

M. J. Balta, in his note on "Fosiles de Carabaya,"[2] mentions the occurrence of graptolites and annelid burrows at Huayna Tacuma, Santo Domingo, in the province of Carabaya. I am unable to find this locality on any map I have consulted, but Mr. Jessop tells me there is a Santo Domingo a few miles from where his graptolites were found, and this is probably the place indicated. M. Balta refers his graptolites to *Diplograptus palmeus*, Barrande, and *D. pristis*, His., and he remarks that only Lower Silurian rocks have at present been observed in South America. The genus *Diplograptus*, however, is not confined to Lower Silurian (Ordovician) deposits, and if the reference of specimens to *D. palmeus* and *D. pristis* be correct, then, while the latter points to beds of Bala age or the uppermost part of the Lower Silurian, the former, *D. palmeus*, indicates Upper Silurian rocks, that is, strata of Llandovery or Tarannon age; moreover, Salter had already in 1861 recognized Upper Silurian fossils among those brought over by David Forbes.

The *Diplograptus* obtained by Mr. Herbert J. Jessop, whether referable to *D. truncatus*, Lapw., or to a new but closely allied species, may be taken as indicative of beds near the uppermost part of the Lower Silurian.

So far as we can judge from the evidence of the graptolites now known to occur in Central South America, there are in that country deposits of Arenig or Llandeilo age with the characteristic *Didymograptus Murchisoni*; beds approximately of Bala age, with *Diplograptus pristis* and *Diplograptus* near to *truncatus*; and possibly strata of Llandovery age, as indicated by *D. palmeus*. It is to be hoped that before long definite graptolitic evidence of Upper Silurian rocks will be obtained by the discovery of some characteristic Monograptids.

[1] Zeitsch. deutsch. Geol. Gesell., vol. xlix (1897), p. 274.
[2] Rev. Cienc, Lima, vol. i (1898), p. 7.

III.—The Rift Valleys of Eastern Sinai.[1]

By W. F. Hume, D.Sc., A.R.S.M., F.G.S., etc.

IN this paper the author deals with some of the results obtained in the course of a survey of Eastern Sinai during the season of 1898–99, his remarks being based on a map carefully prepared by his colleague, Mr. H. G. Skill, F.R.G.S., and on his own topographical and geological observations.

The region specially under consideration is bounded on the west by the central range of Sinai, which is familiar to every Indian traveller, forming as it does a prominent rock-wall to the east of the Gulf of Suez. This mountain mass in reality consists of a series of narrow crests separated by few but high mountain passes, and capable of being traversed only by heavily loaded camels at two points, viz. at the head of Wadi Tarfah and Wadi Hebran. If this range be crossed, and Mount Sinai (Jebel Musa) itself ascended, the view to the east is decidedly disappointing. To the north-east the long white limestone wall of Jebel Gunnah runs more or less east and west, far to the east breaking into isolated masses, and ending in the fine truncated cone of Jebel El Ain. South of, and parallel to it, extend sandy plains and precipitous plateaux of sandstone, these being succeeded by an apparently flat or undulating granite plateau (the rift-valleys in it being hidden), out of which sharp-peaked mountain masses rise as isolated projections or long ridges. To the south-west is a mountain-wall, which hides all the southern land from view, and constitutes the most important scenic feature in Eastern Sinai, extending across the country from the Central Range to the Gulf of Akaba. This *Transverse Divide* claims special attention, not only from the fact that it separates two different types of country, but also because at many points these two regions are at markedly different levels, there being an abrupt fall to the south. The divide is also crossed by five passes, which all have this remarkable feature in common, viz.: *that the valleys they connect form five roughly straight lines, all parallel to one another and to the Gulf of Akaba, that is, running in a direction somewhat west of south.* Two of these are then specially considered with a view to showing that they belong to the category of Rift Valleys, of which the Gulf of Akaba is itself a striking example, it being premised that these are not necessarily single depressions, but rather a series of basins or grooves separated by barriers, which, though higher than the main valley, are of no great altitude compared with the bordering hills. Thus, the Shelala Um Raiyig rift is shown to have a length of over 72 kilometres, being almost perfectly straight and bounded by very steep slopes throughout the greater part of its course.

The geological features are still more striking, the hills on the

[1] Abstract of a paper read by permission of Sir William Garstin, Under-Secretary of State for Public Works, and Captain H. G. Lyons, R.E., Director-General of the Egyptian Survey Department, before the International Geological Congress at Paris, August, 1900.

two sides being frequently of different geological structure, this contrast having often a very marked effect upon the scenery, as, for instance, where the rift separates the granite range of Ashara from the felsitic hills of Ferani, the former rising in sharply peaked red-coloured crests scored by wild gorges, while the latter are of dark-green colour, and possess less rugged outlines.

Still more noteworthy is the presence of sandstones in the valley itself, having all the typical characters of the Nubian Sandstone, yet situated 25 kilometres south of the main mass of that formation; similarly, at the head of Um Raiyig, a ridge of Cenomanian limestone, with sandstone at its base, block the valley, being enclosed between two walls composed of Nubian Sandstone resting on granite. Still further to the north the reverse is met with, a granite ridge running north and south, rising steeply through the surrounding sedimentaries. The examination of the relations of the beds over the area shows that the actual displacement of strata in the production of the rift varies from 200 to 600 metres (2,000 feet).

The Raib Melhadge rift is in some respects even more striking, the granite range extending far further to the north on its eastern than on its western border, which for some distance is formed by lower country, geologically a complex of granite, sandstone, and Cenomanian limestone. As a result, in the upper part of Wadi Raib, Cretaceous limestone forms low ridges dipping steeply eastward at the foot of a granite range, which rises immediately above them to a height of over 300 metres. Descending Wadi Raib the conditions become simpler, the Nubian Sandstone on the west giving way to granite cliffs, and the valley becoming a broad highway bounded on both sides by precipitous height. Yet scattered all along its course are low hills of white Nubian Sandstone, and in one place Cenomanian limestone, *so that the surprising result is realized, that Cretaceous fossils were collected from a limestone on both sides of which tower granite cliffs to a height of over 500 metres* (themselves in places capped by Nubian Sandstone), *the extent of dislocation being here at least 700 metres.* Further to the south, the same rift gives rise to a Coastal Watershed Range of some importance.

The other valleys are considered to be rifts on account of their parallelism to those already described, while they also must have been produced by the same series of movements which gave rise to the Gulf of Akaba.

Correlation of Eastern Sinai Rifts with those of neighbouring districts.—In returning from Eastern Sinai the writer was struck by the resemblance of the western valleys to those already described, the clefts, viz. Nagb Hawa and El Watiyeh, which break through the granite hills, barring the Sinai convent region to the north, being the continuations of remarkable lines of depression which can be traced far to the north-west. One of these, which includes the Convent Valley and runs to Wadi Suwig, is especially straight and well defined, but, in common with the other western valleys, is parallel, not to the Gulf of Akaba, but to the Gulf of Suez.

The conclusion arrived at is as follows:—To the *west* of a north-south line (practically longitude 34° E.) extend a series of N.W.–S.E. rifts, the *Suez* type, which include not only the Western Sinai valleys and the Gulf of Suez, but also Wadi Qena, and in all likelihood part of the Nile Valley itself; while to the *east* of this line is an *Akaba* rift-series, not only giving rise to the Gulf of Akaba, but to all the important longitudinal valleys of Eastern Sinai, and probably producing effects on the opposite coast of Midian comparable for extent and interest to those of Egypt itself. A third, or *transverse*, type of dislocation is also considered, special attention being called to the *regularity* and *parallelism* of the valley directions. Thus, in a space north of the transverse divide, the valleys run mainly east-of-north, west-of-south, or *north-east*, while in other parts of the eastern side of the peninsula the dominant trend is slightly east-of-north, west-of-south, or *south-east*. On the western side, on the contrary, they run north-west and south-east, or south-west. Many of these transverse valleys are in places deep clefts, bounded by precipitous rock-walls, but the geological evidence of rifting is wanting. The general conclusion is thus stated, after a summary of the leading results:—The principal features of Southern Sinai have been produced by *dislocation* rather than *erosion*, fracture in three directions, either directly proved or in the highest degree probable, having determined the general structure of the country. It is, in fact, the meeting-point of two great longitudinal rift-systems, parallel to the Gulf of Suez and Gulf of Akaba respectively, traversed by a third or transverse type, the result being the apparently intricate maze of sharp crest and deep valley characteristic of this region.

Note.—It should be observed that the Akaba system of rifts does not extend far south of lat. 28° N., the ranges to the east of the Red Sea being apparently also of the Suez type.

IV.—Geology of Eastern Sinai.[1]

By W. F. Hume, D.Sc., A.R.S.M., F.G.S., etc.

THE paper under consideration deals briefly with the geological features of Eastern Sinai, and more especially with the characters of the sedimentary rocks developed in that region, a short note on the igneous rocks being also appended. The subject is treated under the following headings:—

I. Pebble Gravels, Travertine, etc.
II. Coral Reefs.
III. Cretaceous Limestones of Cenomanian age.
IV. Nubian Sandstone.
V. Igneous Rocks, etc.

I. Pebble Gravels. — Attention is here again called to the remarkable development of high gravel terraces in the principal

[1] Read by permission of the Egyptian Government before the International Geological Congress, August, 1900.

valleys, these being often over twenty metres high, the gravels being characterized by the fact that they contain fragments of all shapes and sizes derived from the surrounding hills, largely embedded in a sandy matrix consisting of materials of the same derivation, their source being thus strictly local. While found in almost all the principal valleys and many of the side tributaries, they are often particularly well developed at points where longitudinal and transverse depressions cross one another. Their probable *age* can be but determined on the coast of the Gulf of Akaba, where they are found to overlie raised coral-reefs containing such typical Pleistocene or recent forms as *Laganum depressum* and *Heterocentrotus mammillatus*. The gravels are therefore not earlier than the Pleistocene, thus agreeing with the conclusion arrived at by Mr. Barron for those on the west coast of the Red Sea.

One of the most striking features connected with these gravel plateaux is the perfectly flat nature of their upper surfaces, even in the upland wadis, a character which appears inconsistent with their having been produced by rushing torrents, but in accordance with the hypothesis of their formation in lakes or marine fjords. Unfortunately, no shells having been obtained in these beds, their mode of origin still remains doubtful.

Attention is also called to several special varieties of these gravels, the most notable being :—

(*a*) The *Manganiferous Pebble Gravels of Sherm*, in which the cementing material of the conglomerate consists of the hydrous black oxide of manganese, psilomelane, the beds being in places as much as four metres thick, while underneath are strata coloured red by ferruginous ochre. These gravels are closely connected with a core of red granite, ending abruptly where the latter is no longer exposed at the surface, and only overlying it along the edge where it faces the sea. It is of interest to note that the S.S. "Pola" expedition found manganiferous deposits forming on the floor of the Gulf of Akaba, a fact which also suggests the marine origin of the Sherm Gravels.

(*b*) *Oolitic Valley Deposits.*—An oolitic rock is described from the neighbourhood of Ras Muhammed, whose components closely agree in their characters with oolitic grains found by Professor Walther at the mouth of Wadi Dehêse, near Suez, and which he believed to be a marine deposit *in statu nascendi*, mineral fragments being enclosed by successive calcareous layers.

In Wadi Hashubi, where these beds are best developed, they are composed of grains of quartz and orthoclase, cemented by carbonate of lime, which frequently surrounds them in a series of concentric coats, while the strata themselves also show traces of ripple-marking and very fine sun-cracks. In the lower part of the valley they are often strongly current-bedded, and contain lenticular masses of pebbles, while in its upper part they give rise to striking ravines, bounded on both sides by vertical walls of the light-coloured sand-rock. An interesting feature, too, is the height at which these beds are met with, a typical example being still present at 696 metres

above sea-level, so that, if its marine origin be admitted, a differential movement of at least 2,000 feet has taken place in the southern end of the peninsula during comparatively recent times.

(*c*) *Gravels cemented by Calcite.*—At the mouth of Wadi Nasb, near Dahab, the gravels composed of igneous rocks are cemented together by crystalline calcite developed in scalenohedra (dog-tooth spar), while in the hills themselves the igneous fragments are enclosed in well-marked *travertine*, especially in the smaller water-courses.

The theoretical deductions which may help to explain the presence of the various types of gravels are thus summarized :—

1. In South-Eastern Sinai earth-movements have produced three high watershed lines, only one of which is now broken through. If these were formed at the same period all the water draining into the basin enclosed by them would collect to form narrow lakes. This would account for—

(*a*) The flat character of the plateaux.

(*b*) The absence of marine organisms.

2. A marine depression, resulting in the invasion of the sea, and amounting to at least 700 metres, is also suggested, and might account for—

(*c*) The oolitic beds of Wadi Hashubi.

(*d*) The manganiferous gravels of Sherm.

(*e*) The travertines of the higher valleys.

(*f*) The calcite-cemented gravels of Nasb.

This hypothesis would also account for their flat character, and only the absence of marine organisms prevents the absolute acceptance of the view that many of these gravels were laid down beneath the surface of the sea. Indeed, it is of interest to note that Mr. Beadnell has obtained these calcite-cemented gravels and travertines in his Nile Valley lacustrine series, thus affording an additional reason for not arriving at hasty conclusions regarding the marine origin of those in Sinai.

3. A subsequent elevation, accompanied by earth-movements resulting in the uptilting of the older coral-reefs, brought the formation of these special features to a close, the gravels subsequently formed being now distributed irregularly over the surface, in places overlying the oolite beds, and being interbedded with the younger Pleistocene coral-reefs.

II. Coral Reefs and Raised Beaches.—This portion of the paper opens with a correction of Professor Walther's statement that the Gulf of Akaba is poor in coral-reefs, it being pointed out by the author that his colleague, Mr. Skill, had now practically mapped continuous reefs from Dahab to Ras Muhammed. This *Fringing Reef* and the isolated coral terraces, up to 25 metres high, standing only a little way back from the sea-shore (viz. the *Lower Coral Series*), are first considered, and shown to be typically Pleistocene, the raised beaches which in many places line the shore being closely associated with them. The *Upper Coral Limestone* or Older Fossil Reef of Walther, though *apparently* overlying the lower one, is

evidently of older date, the coral having undergone much alteration and being now of a dirty brown colour, though still in large measure possessing the cavernous character of a modern reef. The fauna of these beds has not yet been fully studied, but there is sufficient evidence to show that we have here a remarkable combination of Pectens of older aspect and Mediterranean character, associated with modern Erythræan species similar to that revealed by a study of Mr. Barron's collection of shells from the older reef on the west side of the Red Sea (see R. Bullen Newton, GEOL. MAG., Dec. IV, Vol. VII, pp. 500–514 and 544–560, Nov.–Dec., 1900). Thus, in one bed of this series, *Pecten Vasseli*, Fuchs, and *Chlamys latissima*, Brocchi, are associated in the same bed as *Echinus verruculatus*, previously only recorded from Mauritius (identified by Dr. Gregory). South of Sherm there is a tilted series of coral-reefs, rising nearly 200 metres above sea-level, whose fauna, although very obscure, is probably very early Pleistocene, judging from similar beds occurring on the west side of the Gulf of Suez. It is of special interest to note that these older reefs are only present at the southern end of the Gulf of Akaba.

After maintaining the general proposition that the coral-reefs here are formed in a region of elevation, the question is raised (on the ground of the observation made by Walther that an apparently dead coral-reef was present 6 metres below the present one), whether this elevation is being continued, and it is pointed out that the formation of bays at the mouths of several of the principal valleys suggests that a small local depression is at present taking place in the Gulf of Akaba, which thus differs from neighbouring regions. The writer then considers the series of questions which Professor Walther set himself to answer in his "Die Korallenriffe der Sinai-halbinsel," and agrees with him—(1) that a coral-reef (*sensu stricto*) does not attain any great thickness; (2) as to the rôle which detrital materials play in filling up a coral-reef; and (3) the passage of coral limestone to dolomite by the increase of magnesia. On the other hand, he has been unable to accept Walther's view as to the basis of a coral-reef, the latter laying stress on the importance of compact sedimentary rocks as a base compared with igneous rocks, while in the paper under discussion, after pointing out that the fringing reef of the Gulf of Akaba is largely founded on igneous or metamorphic rock, the writer maintains that the deposition of a coral-reef is practically independent of the nature of the rock forming its base, red granite, diabase, sandrock, and marls (probably also gneiss and hornblende-granite) having been noted as its basal members.

III. CENOMANIAN LIMESTONES; IV. NUBIAN SANDSTONE.—This is a description of the relations and characters of the strata at the northern end of the area examined, limestones forming the main escarpment of Jebel Gunnah overlying a highly characteristic striped series of green marls containing such typical Cenomanian fossils as *Hemiaster cubicus*, *Pseudodiadema variolare*, and *Heterodiadema libycum*. These marls are themselves only the surface capping of

a thick series of white sands, which are now cut deeply into by ravines, giving rise to battlements and castellated ridges, sometimes over 100 metres high, forming one of the most striking features on the road from Sinai to Akaba. These are based on a series of variously coloured ferruginous sandstones, forming broad, low, smooth plateaux, themselves resting on a planed-down surface of granite. Unfortunately these sands and sandstones are all unfossiliferous.

The thicknesses in Jebel Gunnah are as follows :—

	metres.
Compact limestones, with few fossils ...	100
Striped Cenomanian marls	20
Sands and sandstones	207
Total thickness ...	327 (over 1,000 feet).

The most important points noted are:—(1) The Nubian sandstones resting on a planed-down surface of granite; (2) the Cenomanian beds belong to Professor Zittel's 'Africano-Syrian' series, which since Mr. Beadnell's discovery of these beds in Baharia Oasis are shown to have an enormous extension north of latitude 28° N., while Dr. Schweinfurth has shown them to be of great thickness to the north of the Red Sea Hills; (3) the dip and present position of the beds show that these strata once extended over the whole of the present igneous mountain region; (4) the Carboniferous sandstones of Western Sinai are apparently absent.

V. The Igneous Rocks of Eastern Sinai. — After a brief general description this portion of the paper lays stress on the importance of *dykes* of every petrographical variety, which, though the youngest members of the igneous series, never pass into the Nubian Sandstone, so that they are at least Pre-Cretaceous. While generally trending N.N.E. and S.S.W., there is frequently a second system, running practically at right angles to this direction. Though in general aspect resembling the mountains on the opposite side of the Red Sea, the fundamental rocks of the central axis of the peninsula are *granitoid gneiss* and *hornblende-granite*, not the *red granite* which forms many of the main summits in the Red Sea Hills. The latter is, however, also widely distributed in the peninsula itself.

Of special interest are beds of andesite, tuff, and agglomerate, which form some of the principal summits, capping the granite and gneiss, while in the Ferani range, etc., this *Volcanic* series is closely associated with a metamorphic type, varying from spotted slates and slightly foliated mica-schists to dark-green chlorite and hornblende-schists pierced by innumerable dykes of dolerite. Some special points are dealt with in closing, such as the development of gneisses on a magnificent scale in Wadi Um Gerat, the importance of *tourmaline-granite* in some of the southern summits, the presence of *spherulitic* felsites forming dykes in many parts of the district, and the probable absence of the *basalt* recorded near Sherm by Burckhardt.

V.—The Connection of the Glacial Period with Oscillation of the Land, especially in Scandinavia.

By Dr. Nils Olof Holst. Translated by F. A. Bather, D.Sc.

[In a recently published paper[1] Dr. N. O. Holst, of the Geological Survey of Sweden, has given a detailed description of the Post-Glacial deposits of the Baltic Sea and the Gulf of Bothnia. The paper is accompanied by a map showing the chief points of observation. The determination of the different horizons depends on (1) the stratigraphy; (2) the sub-fossil diatomaceous flora; (3) the sub-fossil higher flora. The stratigraphical evidence is in the form of numerous sections, taken all along the coast. The diatoms are used chiefly, but not solely, to distinguish the marine from the fresh-water deposits; their determinations, nearly 3,000 in number, are due to Professor P. T. Cleve and his daughter, Dr. Astrid Cleve. The remains of the higher plants have been determined by Dr. Gunnar Andersson.

The fresh-water (*Ancylus*) epoch and the salt-water (*Litorina*) epoch are divided by the author as follows:—

1. The oldest *Ancylus* epoch, the deposits of which age in southern Sweden partly are barren, partly contain Arctic plants.

2. The middle *Ancylus* epoch, of which the deposits contain the remains of fir and birch. During this epoch the land-ice melted away from the lower parts of central Sweden, and the sea came into the Baltic, making the water temporarily salt.

3. The youngest *Ancylus* epoch, or the older half of the oak epoch.

4. The *Litorina* epoch, or the younger half of the oak epoch, when the present communication with the sea was opened, and the water of the inland sea, which during the *Ancylus* epochs had been fresh as a rule, now became salt.

The fact that the climate became temporarily colder in the middle of the *Litorina* epoch is established by finds of boreal diatoms: *Navicula semen, N. amphibola, Pinnularia streptoraphe*, etc.

Wider interest attaches to the concluding pages (113 et sqq.), in which the author deals with the question of oscillation of the land in Scandinavia and with the explanation of the Glacial Period, on which matters he expresses some new views. We therefore offer a full translation of this part of Dr. Holst's memoir.]

I HAVE elsewhere[2] shown that the events immediately connected with the melting of the Scandinavian land-ice occurred in rapid succession. The same was the case with the oldest Post-Glacial events. Thus it has been demonstrated in the present paper that the Glacial marine clay and sand, deposited along the present coast

[1] "Bidrag till kännedomen om Östersjöns och Bottniska Vikens postglaciala geologi": Sveriges Geologiska Undersökning, Afhandl., ser. C, No. 180. 8vo; 128 pp., 1 map; 1899 (published March, 1901).

[2] N. O. Holst, "Har det funnits mer än en istid i Sverige?": Sver. Geol. Unders., 1895, ser. C, No. 151, see pp. 36–39. German translation by W. Wolff, "Hat es in Schweden mehr als eine Eiszeit gegeben?" pp. 38–42; Berlin, 1899.

of Blekinge and of the Kalmar district, were exposed by elevation of the land and were weathered before the deposition of Post-Glacial beds upon them had begun. It was this elevation of the land that connected Scania with Denmark and permitted the immigration of the larger land animals.[1] It appears as though not only this elevation, but also the succeeding depression, during which the oldest *Ancylus* beds were deposited in the government districts of Blekinge and Kalmar, took place in the former district before the Arctic plants had found time to immigrate thither. But when this depression reached the neighbourhood of Kalmar, the Arctic plants were already there. In Blekinge and the Kalmar district there followed an elevation, probably of less importance, and it was not until the succeeding depression, which marks the beginning of the middle *Ancylus* epoch, that southern Sweden saw the deposition of beds that can be paralleled with the oldest Post-Glacial beds of central Sweden. But these latter lie without break conformably on the Glacial beds. This implies that southern Sweden incurred two elevations and their succeeding depressions, in which central Sweden had no share. No explanation of these facts is more natural than that *southern Sweden, relieved of its ice-load, rose*[2] *and began to oscillate, while the land-ice continued to keep central Sweden depressed.* In other words, this means that there was a clear and definite connection on the one hand between the weight of the land-ice and the depression of the land, on the other hand between the removal of the weight and the elevation of the land. But this is a result pregnant with the most important consequences for the whole of glacial geology.

It is clear that the depression, if dependent on the weight of the land-ice, should yield evidence of having been greater the nearer one comes to the centre of the ice; in other words, the nearer one comes to those regions where the ice-load was greatest. A glance at a map indicating the extent of the depression shows at once that such was the case.[3] While in the south the curve of depression

[1] That the aurochs already existed in the province of Kalmar at the beginning of the fir period, i.e. at the beginning of the middle *Ancylus* epoch, has been proved on a preceding page. But the only Post-Glacial elevation of importance that occurred in southern Sweden before that period was the very one that immediately followed the deposition of the Glacial marine beds.

[2] It is quite probable that this elevation during the oldest Post-Glacial Period also reached northern Germany. If such was the case, may it not in part have been the reason why the Vistula and Oder during that period did not flow into the Baltic but had their outlet through the Elbe? Cf. F. Wahnschaffe, "Die Ursachen der Oberflächengestaltung des norddeutschen Flachlandes"; Stuttgart, 1891.

It is also very probable that the same upward pressure of the land outside the periphery of the land-ice took place in North America, and that this affords the correct explanation of many phenomena which otherwise appear inexplicable.

[3] See Gerard De Geer, "Om Skandinaviens geografiska utveckling," 2. Kartor, pls. 2, 3, 4; Stockholm, 1896. The criticism must, however, be passed on these plates that they do not, as they profess, give the depression-curves for different epochs of the melting of the ice, but that all three show only the same thing, namely, the extent of the depression at the time of the final melting of the ice. According to the plates, the depression during the melting of the ice remained the same for a long period, while, on the contrary, all the facts tend to prove that throughout that time the extent of the depression altered very rapidly.

that crosses the southern Baltic, and in the east that which passes by the southern end of Lake Ladoga, both mark zero, as one proceeds from south to north or from east to west the curves mark higher and higher numbers, until the greatest depression known, so far as established by tracing the highest Glacial marine coastline, attains in northern Sweden no less than 280 metres.[1] Lately, indeed, it has been said that in Norrland the Glacial marine coastline is at a lower level in the interior than near the present coast. But if that is the case, we may recall the fact that the highest Glacial coastline was formed at different times in different places. It is therefore quite possible that the apparently abnormal conditions in Norrland spring from nothing else than the formation of the Glacial coastline, first at the coast and afterwards at the interior, for the simple reason that "the ice did not melt from the interior of Norrland until the elevation had been in progress for some time."[2] The conditions in Norrland are therefore in no way opposed to the rule that increased depression and increased ice-load point in the same direction.

Scandinavia under its load of land-ice may be compared to a depressed spring. When the load is removed the land tends to resume its original position. This explains the great rapidity with which the land rose at the close of the Ice Age, a rapidity for which in my above-quoted paper of 1895 I gave conclusive evidence, although I then did not fully understand what caused the rapid rise of the land. But although this demands a certain elasticity in the crust of the earth, yet it cannot be supposed that this elasticity was so great as to permit the land, pressed down as it was during a large part of the Ice Age, to regain the state of equilibrium in which it was at the beginning of the Ice Age; some of the upward tension must in the meantime have been neutralized. The highest Glacial marine coastline therefore marks only the final result of the depression at the moment when the ice melted. Now the position of this line no less than 280 metres above sea-level is alone enough to show that the depression was considerable. But for the reason just mentioned this height indicates *only a part* of the Glacial depression. This line of argument has already led us to the conclusion that at the beginning of the Ice Age Scandinavia lay much higher than now. But that this elevation was in itself enough to afford a simple and natural explanation of the Glacial Period will be proved in the sequel by more conclusive evidence.

From what has been said it is clear that the Glacial and Post-Glacial changes of level in Scandinavia (and the same applies to North America) are due to a special cause, and therefore cannot be compared with volcanic or continent-building oscillations. All attempts to generalize from such comparisons are foredoomed to failure.

[1] A. G. Högbom, "Till frågan om den senglaciala hafsgränsen i Norrland": Geol. Fören. Stockholm Förhandl., 1899, xxi, p. 595.

[2] A. G. Högbom, "Om högsta marina gränsen i norra Sverige": Geol. Fören. Stockholm Förhandl., 1896, xviii, p. 488.

No better success has attended the attempts to discover the cause of the Glacial Period in directions other than that here indicated. Especially is this true of the struggles after some far-fetched astronomical explanation of this terrestrial phenomenon. The geologist who perambulates the universe in search of such explanations may be likened to an erudite bookworm who turns his study upside down in search of his pencil, which all the time is behind his ear.

To the view here stated as to the cause of changes of level in Glacial and Post-Glacial times, I have been led by my own researches, and my ideas already tended in this direction before I realized that T. F. Jamieson, and other geologists after him, had expressed views almost identical with my own. Subsequently I have perused Jamieson's writings on this subject more closely, and, with sincere admiration for his acumen, have found that so early as 1865,[1] supported by comparatively few observations, he put forward the leading idea which in 1882[2] he developed in more detail, and which, confirmed as it now is by more numerous observations, can without hesitation be accepted as the only correct one.

From the papers by Jamieson I think it right to make the following instructive extracts :—

"It has occurred to me [Jamieson] that the enormous weight of ice thrown upon the land may have had something to do with this depression [the great glacial depression]. . . . . We don't know what is the state of the matter on which the solid crust of the earth reposes. If it is in a state of fusion, a depression might take place from a cause of this kind, and then the melting of the ice would account for the rising of the land, which seems to have followed upon the decrease of the glaciers." (Q.J.G.S., loc. cit.)

"Assuming the specific gravity of the ice to have been 875, compared with water as 1,000, or in other words to have been seven-eighths of the weight of water, then the weight of a mass of ice 1,000 feet thick would be 378 pounds to the square inch, or equal to fully 25 atmospheres, and would amount to 678,675,690 tons on every square mile. If the ice was 3,000 feet thick, it would at this rate amount to over 2,000 million tons on the square mile." (Geol. Mag., 1882, p. 403; Jamieson here quotes some geologists who have supposed that the thickness of the ice has been much greater, and then he continues as follows :—) "It is evident that a thickness of even 3,000 feet of ice will give us a weight by no means despicable, a weight which would require a marvellous rigidity indeed in the earth beneath it to sustain such a load without yielding in some degree" (p. 404).

"That the crust of the earth is flexible and elastic the phenomena of earthquakes sufficiently demonstrate. The surface heaves like the billows of the sea, sometimes causing trees to bend so as to

[1] T. F. Jamieson, "On the History of the last Geological Changes in Scotland": Quart. Journ. Geol. Soc., 1865, xxi, p. 178.

[2] "On the Cause of the Depression and Re-elevation of the Land during the Glacial Period": Geol. Mag., 1882, Dec. II, Vol. IX, pp. 400 and 457.

touch the ground with their tops, or tossing up flagstones into the air so as to make them come down bottom upwards," etc. (p. 404.)

"If upheavals and depressions of the land have not been caused by changes of pressure, it may be asked, what is it they have been caused by?" (p. 405.)

"If beneath that part of the surface which was affected by the heavy pressure of the ice, there happened to be a quantity of lava in a fluid state, the result might be to cause an outburst of the lava to take place at some more distant point. This would relieve the tension and lead to a permanent depression of the ice-covered area. For example, in North America the great fields of ice that lay on certain portions of that continent by their downward pressure may have occasioned some of those extensive eruptions which seem to have taken place in the region of California after the commencement of the Glacial period. The volcanic phenomena of Iceland in like manner may have been affected by similar causes. That there has been a considerable permanent depression of some of the most heavily glaciated regions since the commencement of the Glacial period, I think there is much reason to believe. The features of the fjord districts of Norway and the West Highlands of Scotland, and of British Columbia, for example, seem to show this; for these coasts have all the appearance of depressed mountain lands, which have been cut and carved by streams and glaciers far beneath the present level of the sea." (p. 405.)

"It seems likely that there might be a tendency to bulge up in the region which lay immediately beyond this area of depression; just as we sometimes see in the advance of a railway embankment, which not only depresses the soil beneath it, but also causes the ground to swell up further off." (p. 461.)

So far Jamieson. His ideas have, before me, been shared by Whittlesey, N. S. Shaler,[1] and Warren Upham,[2] the last-mentioned having developed them further. Upham calls our special attention to the indisputable glacial formations that date from the Carboniferous or Permian periods, as that in South Africa at 30° S. lat.,[3] in India at only 20° N.,[4] as well as in Australia,[5] and he correlates these phenomena with the mountain-building that took place during that time. Of the glaciated areas here mentioned I have myself visited that in Australia, in the neighbourhood of Bacchus Marsh, just west of Melbourne (37°–38° S.), and can confirm the correctness of the descriptions given. Here occurs a typical boulder-clay, of blue

[1] "Fluviatile Swamps of New England": Amer. Journ. Sci., 1887, ser. III, vol. xxxiii. See pp. 220, 221.

[2] "Probable Causes of Glaciation," Appendix A to G. F. Wright's "The Ice Age in North America"; New York, 1891. See also Amer. Geol., 1890, pp. 327 et sqq.; and Amer. Journ. Sci., 1891, vol. xli, p. 33.

[3] A. Schenck, "Ueber Glacialerscheinungen in Südafrika": Verhandl. des VIII deutschen Geographentages in Berlin, 1889.

[4] R. D. Oldham, "A Manual of the Geology of India," Calcutta, 1893. See pp. 157 and 198.

[5] T. W. E. David, "Evidences of Glacial Action in Australia in Permo-Carboniferous Time": Quart. Journ. Geol. Soc., 1896, lii, p. 289.

colour, containing glacially striated stones of many kinds of foreign rocks. This boulder-clay is overlain by sandstone with *Gangamopteris*, belonging to the Carboniferous or the Permian system. What cast suspicion on the glacial deposits of Australia was the great thickness ascribed to them, namely, as much as 5,000 feet. But this estimate, which sounds so fantastic, is really founded on a mistake that arose in the following way:—In the valley where this thickness was calculated the morainic beds are obliquely inclined one above the other. By measuring each of these beds and adding the apparent thicknesses together a total was obtained which naturally was not the true vertical thickness. That this in reality is not so extraordinarily great is clear from the fact that the solid Silurian rock crops out both at the bottom and on the side of the valley in question. For a 5,000 foot thick moraine to find room between these outcrops, it must lie in a very deep hollow of most unusual and inexplicable shape.

For my part I think Upham must be accounted right in his contention that the glacial phenomena of South Africa, India, and Australia can be explained only on the supposition that these districts formerly lay much higher than now. Especially does this apply to the Indian glacial district, situate only 20° from the equator. There is no place here for the interglacialist hypothesis, and if a former elevation be not admitted for this district we may justly ask what else can have produced glacial phenomena so near the equator. On the other hand, we may adduce the fact that Kilima Ndjaro in East Africa, said to be about 6,000 metres high, exhibits glaciation although only 3° from the equator.

But if an elevation of the land in equatorial regions can produce glaciers, what glacial results may we not expect from an elevation in the latitude of Scandinavia, Greenland, and North America? The question is reduced to this: Can we show that during Quaternary times such an elevation really did take place in the three great glacial districts? It is as a rule difficult to prove former elevation of the land if the region once raised now lies sunk below sea-level; but in proportion as the oceans that bound North America and Scandinavia have been more closely investigated this proof has been forthcoming, and a considerable elevation of Quaternary age is now fully established both for North America and Scandinavia.

As regards North America, many geologists, of whom I shall cite only J. W. Spencer,[1] have demonstrated that the larger rivers on the eastern side of the continent, from the Mississippi up to the St. Lawrence, have channels clearly excavated beyond the coast to a depth below the sea of "3,000 feet or more"; and this naturally indicates that formerly the land was elevated to a corresponding height. Similar observations have been made on the Pacific coast of North America. That this elevation took place at a relatively recent period follows from the fact that the submarine channels are not filled up as they would otherwise have been.

[1] "The High Continental Elevation preceding the Pleistocene Period": Bull. Geol. Soc. Amer., 1890, i, p. 65.

Like observations have been made on the coast of Norway, where the deep fjords continue as submarine valleys beyond the present coast to a great depth. For these to have been carved out by the rivers of a past age, the land must of course have lain much higher than now. The so-called 'Norwegian Channel,' if, as is probable, it represents an ancient river-bed, proves the same thing.

The Scandinavian Pre-Glacial elevation, however, was not confined to the coast of Scandinavia, but evidently affected a large part of the bottom of the present North Atlantic, both westwards to the east[1] coast of Greenland and southwards to the south part of England. So far as Great Britain is concerned this elevation is undeniable. The mere existence in this country of a Pre-Glacial mammalian fauna, obviously exterminated by the Ice Age[2] and partly reminiscent of more southern regions (elephants of various species, mammoth, mastodon, lion, hyæna, etc.), is enough to presuppose a land-connection between the continent and England and Ireland, so that the animals could cross to these islands.[3] But these mammals did not merely *wander across* the English Channel and the southern parts of the North Sea; they also *inhabited* the districts now sunk beneath the waters, as may be inferred from the "almost incredible" "quantity of teeth and bones belonging to the mammoth, woolly rhinoceros, horse, reindeer, and spotted hyæna, and other animals, dredged up by the fishermen in the German Ocean" (op. cit., p. 365). That the animals lived here at no distant date follows from the fact that their bones are found on the very surface of the sea-floor, as well as from the mixture of remains of Pre-Glacial animals with those of the reindeer, as to whose contemporaneity with the Ice Age there can be no doubt. Finds of this boreal species on the floor of the North Sea show further that the elevation still existed when the Glacial Period was setting in.

Furthermore, submarine peat-bogs along the coast of England, as well as the discovery of the fresh-water bivalve, *Unio pictorum*, and *shore* shells at a greater depth than 200 feet in the English Channel (op. cit., p. 364), bear clear witness to an elevation of the land in Quaternary times.

But the depth of the English Channel and of the southern part of the North Sea is not very great—at the southern end of the Dogger Bank not more than 13–16 metres—and a raising of the sea-bottom from 30 to 50 metres would be enough to bring a large

[1] 'Västra' (west) in original; correction by the author.

[2] H. H. Howorth, "Did the Mammoth live before, during, or after the Deposition of the Drift?": GEOL. MAG., 1892, Dec. III, Vol. IX, pp. 250 and 395.

In England the so-called interglacial occurrences of the larger mammals seem to rest only on mistakes or on the estimation of secondary occurrences as primary. Of course they disappear at the same time as the so-called 'interglacial' deposits cease to be interpreted as interglacial, and this is already the case with the majority. Thus the 'middle sand,' formerly the most important of the interglacial formations, is now very generally regarded as glacial. And, so far as I could discover from conversation with English geologists, the idea of a true 'interglacial' period is now almost abandoned by them.

[3] W. Boyd Dawkins: "Cave Hunting, etc."; London, 1874. See p. 362.

part of it above the surface. It may therefore be objected that, even though the land-connection in question may really have existed, still it is in itself no proof of any considerable elevation, certainly not of one great enough to explain the severe climate of the Glacial Period. And this, no doubt, is perfectly true.

But there are other evidences for a much greater elevation in the north-west of Europe. That the agreement between the floras of Scandinavia, Scotland, the Faeroes, Iceland, and Greenland necessarily presupposes a land-connection in Quaternary times, has been long understood. Such a connection involves an elevation of the sea-floor between Scotland and Greenland of about 3,000 feet (891 metres).[1] But did such an elevation really take place during the Quaternary Period? Conclusive proof of it was given by A. S. Jensen,[2] when he demonstrated the logical consequences of the discoveries made by the Ingolf expedition in 1896 during the investigation of the sea-floor between Jan Mayen and Iceland. Here the expedition found at a great depth, reaching as much as 1,309 Danish fathoms,[3] such *shallow*-water bivalves as *Astarte Banksii, A. borealis, A. compressa, Cardium ciliatum, C. groenlandicum, Cyrtodaria siliqua, Macoma calcaria, Saxicava arctica,* and *Yoldia arctica.* These marine molluscs, which can live only at small depths, according to Jensen in not more than 100 fathoms of water, occur in great numbers, and it is quite clear that they have lived where their shells now are met with. These discoveries therefore prove that the sea-bottom between Scandinavia and Greenland once lay more than 1,200 fathoms (2,138 metres) higher than now. As for the date of the elevation, Jensen justly observes that the occurrence of *Yoldia arctica* is enough to show that it took place during the Glacial Period. During which part of that period the elevation existed is not discussed by Jensen, but it is most reasonable to refer it to the beginning of the period, when an elevation is established both for England and Scandinavia.[4] If this elevation started from the Archæan district of Scandinavia and of Greenland, as there is good reason for supposing, then the elevation of Scandinavia must have been greater than that demonstrated by Jensen for the sea-floor between Scandinavia and Greenland. But if the elevation was only of the same, or even approximately the same magnitude, it was still quite enough to afford an explanation of the Glacial Period itself.

But this elevation of the sea-floor between Scandinavia and Greenland carried with it another important consequence, in that it changed this part of the ocean into an inland sea, comparable with the Mediterranean, and united with the body of the Atlantic only by the deep channel between the Shetlands and Faeroes.[5]

[1] See the map to W. H. Hudleston's paper "On the Eastern Margin of the North Atlantic Basin": Geol. Mag., 1899, Dec. IV, Vol. VI, p. 97.

[2] "Om Levninger af Grundtvandsdyr paa store Havdyb mellem Jan Mayen og Island": Vidensk. Meddel. Naturhist. Foren. Köbenhavn, 1900, p. 229.

[3] 8,087 English feet; 2,465 metres.—Translator.

[4] The same elevation also reached Iceland. See Th. Thoroddsen in Geol. Fören. Stockholm Förhandl., 1900, xxii, p. 546.

[5] Cf. Hudleston's map cited above.

From this in turn it followed that the Gulf Stream was completely shut off from the Arctic Ocean and forced to turn south and west of the British Isles, and thus to concentrate its heat-giving energy on central Europe. This explains the mild climate found in a portion of Europe during a stage of Pre-Glacial time.

As shown above, it may be considered as a fact confirmed by known phenomena, that at the beginning of the Quaternary Period portions of the North American continent lay at least 1,000 metres, and Scandinavia still more, perhaps 2,000 metres, higher than now. As for the intervening Greenland, it seems probable that it could not be unaffected by these changes of level, but that it took part in them.[1]

We meet here the legitimate question: What is it that produced such a great elevation in these particular parts of our earth? The answer is that North America, Greenland, and Scandinavia, not merely taken together, but each separately, are the largest areas of Archæan rocks in the world.[2] The remarkable coincidence of the great glaciated districts with the Archæan districts has long since been commented on as peculiar. No explanation, however, has been given of this fact. What it really means I shall here show.

During the Silurian Period Scandinavia was partly covered by the sea, as clearly proved by the numerous patches of Silurian rock. Possibly the same was the case during a part of the Devonian Period. But before the close of that period Scandinavia rose above the water, and probably went on rising right up to the Quaternary Period. At all events the Archæan area of Scandinavia never again sank beneath the sea, as clearly demonstrated by the absence of younger marine formations from within its boundaries. Examination of a geological map of Europe shows that the shore of the later Palæozoic, and still more that of the Mesozoic, sea moved eastwards further and further away from Scandinavia, which seems to imply that, during the long ages that elapsed after the Silurian (or Devonian) Period, Scandinavia continually rose, and involved in its rise a part of the surrounding area.

The course of events on the North American continent was precisely the same. Here the shore of the later Palæozoic and Mesozoic sea moved southwards ever further and further from the rising Archæan area of the north.

On what can this harmony of events have depended?

If so late as the Quaternary Period the crust of the earth was found to yield to the pressure of the land-ice, still more must it have yielded to burdens during the earlier stages of the earth's development. That this was actually the case is shown in Scandinavia itself by numerous instances from Cambro-Silurian times. For some years it has been well known that faults, often accompanied

[1] During my journey to Greenland in 1880 I saw from the sea south of Ivigtut supposed beaches in a situation exposed to the sea at a great height on the mountain slopes. Time, however, did not permit me to examine them. Numerous similar observations are mentioned in "Meddelelser om Grönland."

[2] See Berghaus' "Physikalischer Atlas," Maps 7/8, 9, and 13; Gotha, 1892.

by breccia-formation, may be observed in Scandinavia at many points on the boundary-line between the Archæan and Cambro-Silurian deposits, as on Bornholm, in Scania, on Lake Vetter, in Ostrogothia, Nerike, Dalecarlia, Gestrikland, Jemtland, on the Christiania fjord, on the Kola peninsula, and other places.[1] Even the quite insignificant occurrence of Silurian at Humlenäs in the province of Kalmar can show a similar fault with accompanying breccia-formation. For my part I do not think that any explanation of these phenomena will ever be found more satisfactory than that the earth's crust, which during the Cambro-Silurian periods was much thinner than now, yielded beneath the weight of the Cambro-Silurian sediments. If such were the conditions, we can also understand the immense thickness which the Palæozoic rocks occasionally attain, and which may have arisen by the gradual sinking of the sea-floor in proportion as the formation of sediment proceeded.[2]

But if sedimentation tends to depress the earth's crust, and actually has depressed it in certain places, then to such a sinking there must have corresponded elevation in another place[3]; and it is precisely this elevation above all that has affected the Archæan areas, and particularly the greater ones — those that could, so to speak, move independently—because these areas have not merely formed the thinnest parts of the crust, but have lacked the strengthening influence of the stratified deposits.

This, then, seems to have been the way in which elevation of the Scandinavian and North American Archæan areas was brought about and carried on, until at the beginning of the Glacial Period they had reached such a height that each formed the centre for an ice-sheet.

If the conception put forward in the preceding pages is the right one, it follows that the phenomena which accompany the appearance of an ice-sheet involve such radical and manifold changes within the glaciated area that an Ice Age cannot, so to say, come and go unmarked, but must leave the most obvious traces behind it. Therefore it is that the idea here propounded is utterly opposed to the interglacialist view, and therefore it has been attacked by champions of the latter.[4] The chief objection raised by them to the present explanation of the Ice Age is the following.

Granted, they say, that this might be quite a satisfactory explanation of the Scandinavian, Greenland, and North American ice-sheets, still it is not enough to explain the former small glaciated areas in the Pyrenees, the Alps, the Caucasus, and so forth. To

[1] See "Generalregister" to vols. vi–x of Geol. Fören. Stockholm Förhandl., p. 34.
A fault in Jemtland is described by A. Högbom in his paper, "Om förkastningsbreccior vid den Jemtländska silurformationens östra gräns": Geol. Fören. Stockholm Förhandl., 1886, viii, p. 352.
The Palæozoic faults on the Kola peninsula have been described by W. Ramsay, Fennia xvi, No. 1, pp. 2 and xv; No. 4, pp. 7 and 11.

[2] The same views were expressed by James Hall in the "Palæontology of New York," iii, pp. 69 et sqq.; Albany, 1859.

[3] Cf. J. Hall, op. cit., p. 95.

[4] J. Geikie: "The Great Ice Age," 3rd ed., p. 792; London, 1894.

this, however, it may be replied that these smaller peripheral glacial areas were perhaps directly due to the general sinking of temperature produced by the North European ice-sheet during its maximum extension.

That such a fall in temperature really took place may be considered as proved by the fact that so boreal an animal as the reindeer, during a part of the Glacial Period, had a wide distribution in southern Europe. And, as regards the cause of the smaller peripheral glaciated districts, it may once more be recalled that if a mountain chain be sufficiently raised, no matter by what cause, a glaciated area may be produced when and where you please.

But there is another objection, which, at first glance, seems more weighty. Besides the oscillations of Glacial age, there have in Sweden also been some of Post-Glacial age, partly during the *Ancylus* period, partly during that of *Litorina*. Now, if the pressure of the land-ice and the removal of that pressure afford a valid explanation of the former—and it can hardly be denied that such is the case—still it seems quite impossible that they can explain the latter. Surely the ice-sheet cannot produce oscillations of level some ten thousands of years after its disappearance. So no doubt it seems; and yet this is exactly what the ice has done.

Nowadays it is well known that the Glacial and Post-Glacial areas of depression almost entirely coincide. Not only do the zero curves on the periphery of these areas follow the same course, but the maxima or centres themselves are on the whole the same.[1] It is only the amount of the depression that was different, the Glacial sinking reaching 280 metres, the *Ancylus* sinking exceeding 200 metres (?), and that of the *Litorina* period being about 100 metres.[2]

The conformity now demonstrated between the Glacial and Post-Glacial changes of level points to a common cause. This has long since been perceived, and A. G. Högbom, who remarked the fact, expressed it as follows: "The same factors have governed the oscillations of the land continuously from the Ice Age to the present day."[3] But what can the common cause or common factor have been? To this I reply: Nothing else than the removal of the ice-pressure. When this ceased the Scandinavian area of depression was set in a swinging motion, like a pendulum set free. This area, depressed somewhat lower than the highest Glacial coastline, rises for the first time as the land-ice disappears. This is the late Glacial elevation. It sinks afresh in the *Ancylus* period, and during this depression the highest *Ancylus* beach is formed.[4] But again the area rises, and finally sinks for the third time to the level marked

[1] Gerard De Geer: "Om Skandinaviens geografiska utveckling," 2. Kartor, pls. 4, 5, and 6; Stockholm, 1896.

[2] The arithmetical progression from 100 to 200 and 280 is not regular. May not this indicate that the last figure is too low, and that the Glacial depression was greater than is shown by the highest Glacial marine coastline?

[3] "Om högsta marina gränsen i norra Sverige": Geol. Fören. Stockholm Förhandl., 1896, xviii. See p. 487.

[4] There is no reference here to the undulatory motion of the land-oscillations, but only to their final result.

by the highest *Litorina* beach. The elevation consequent on that is still going on.[1] And it is not too rash to predict that these oscillations will continue until the ever-weakening effect of the impulse given by the land-ice is neutralized by the other terrestrial factors that produce land-oscillations.[2]

From the foregoing pages it appears that "the *Post-Glacial* geology of the Baltic Sea and the Gulf of Bothnia" stand in the closest relation to their Glacial geology. Therefore I have been unable to make the former clear without at the same time throwing some light on the latter.

VI.—On the Fish Fauna of the Millstone Grits of Great Britain.

By Edgar D. Wellburn, L.R.C.P., F.G.S., F.R.I.P.H., etc.

Introduction.

ON June 10th, 1898, whilst on an excursion with the Yorkshire Geological and Polytechnic Society, I found three specimens of fish remains in the Millstone Grits at Summit in Lancashire. Subsequently, on several occasions, I again visited the district and succeeded in collecting a large number of fish remains, and on these, together with a few other specimens which had been found in these rocks at rare intervals, I have based the following paper.

General Remarks.

Brief Description of the Millstone Grit Rocks.

The Millstone Grit rocks may be naturally grouped into three divisions, viz.: (1) the Rough Rock at the top; (2) the Kinder or Pebble Grits at the base; with (3) between them the Middle Grits, which are composed of thick beds of shales alternating with bands of grit rock. The Middle Grits may again be subdivided into four groups, viz., A, B, C, and D beds, A being the uppermost.

The great Pennine Anticline, between Lancashire and Yorkshire, is mostly composed of these rocks, and on the Lancashire side, south-west of Walsden, at the head of the Calder Valley, there are on the south side several splendid exposures of these rocks; in one quarry near Summit, Lancashire, there is a very good section of the D beds of the Middle Grits, and in the shales near the base there are a number of nodular masses composed of impure limestone; it is from these nodules that I have collected the majority of the fish remains.

The nodules are of peculiar conformation, and vary in size, many being 24 inches in length, 18 in width, and 9 or 10 inches

[1] Each successive swing was naturally not only less extensive but shorter than the preceding. From this it may be inferred that the *Litorina* depression prevailed a shorter time than the *Ancylus* depression.

[2] Here, of course, it is only Scandinavia that is alluded to. But the same remarks are largely applicable also to North America, although it is not unlikely that the North American ice-sheet, being much larger than that of Scandinavia, melted later than it. In that case the Post-Glacial epoch must have been shorter in North America than in Europe. Herein may lie the reason why many North American geologists, in their estimates of Post-Glacial time, have arrived in harmony at such low figures as 7,000 to 10,000 years—a far shorter time than that in which the Post-Glacial deposits of Scandinavia were formed.

in depth. At the base of the nodules there is a layer of cone-in-cone, two to three inches in thickness, at the top three to four inches of hard dense limestone, which breaks with a conchoidal fracture, whilst between these the stone is more impure, there being a certain admixture of arenaceous matter, and here the rock will split into laminæ of from a third to half an inch in thickness. The majority of the fish remains were found on these slabs, but others, in a more fragmentary condition, occur in the upper layers of the nodules.

That the nodules were formed under marine conditions is proved by the fact that mixed among the fish remains are shells of *Goniatites, Orthoceras, Aviculopecten, Posidonomya*, etc. In some rare instances plants are found, but only in a very fragmentary and eroded condition, and in the upper portions of the nodules I have in rare instances found corals and crinoids. These taken together point to the fact that the fish-bearing nodules were formed under estuarine conditions.

I have found similar nodules at Wadsworth Moor, Yorkshire, where the late Captain Aitken [1] collected his fish remains, and feel certain that his specimens were obtained from the same horizon as the one at Summit.

Fish remains have also been found in the D Shales of the Middle Grits at the following localities in Yorkshire, viz., Eccup, near Leeds; Boulder Clough, Sowerby, and Kilne House Wood, Luddenden, both near Halifax; and the late Mr. James Spencer, of Halifax, mentions [2] *Elonichthys Aitkeni*, Traq., as occurring in the Rough Rock and the B and C beds of the Middle Grits, but unfortunately he gives no localities.

The collection is of great interest, both from a geological and a zoological point of view—both as largely increasing our knowledge of a fish fauna in a group of rocks whose yield of fossil fish has hitherto been extremely limited, and zoologically in the fact that one genus and several species are new to science, whilst others are placed on record as obtained from these rocks for the first time.

Concerning the appended list of genera and species the following facts stand out as worthy of special mention (in addition to those mentioned above), viz.: (1) the occurrence of the genus *Climatius*, a fish that has hitherto occurred only in the Lower Old Red Sandstones of Forfarshire; (2) the appearance in the Millstone Grits of the genera *Orodus, Psephodus, Pristodus*, etc., for the first time; and (3) the occurrence of the peculiarly interesting Ichthyodorulites, for which I have felt compelled to institute the new genus *Eucteno dopsis*.

Remarks on the Fish Remains.

Family CLADODONTIDÆ.

Genus CLADODUS, Agassiz, 1843.

Cladodus mirabilis, Agassiz, 1843.

The late Mr. Aitken,[3] of Bacup, found teeth of this genus in the

[1] Trans. Manchester Geol. Soc., vol. xiii, p. 36.
[2] Proc. Yorks. Geol. and Polyt. Soc., vol. xiii, pt. 4.
[3] Aitken, op. cit.

D Shales of the Middle Grits at Wadsworth Moor, Yorkshire, and there is also a tooth in the Woodwardian Museum, Cambridge,[1] which shows the characters of the above species. It is from the same locality and horizon.

Family PRISTODONTIDÆ.

Genus PRISTODUS, Davis (*ex* Agassiz MS.), 1883.

Pristodus falcatus, Davis, 1883.

I have found one tooth of this species.

Form. and loc.: D Shales, Middle Grits, Summit.

Family COCHLIODONTIDÆ.

Genus PSEPHODUS, Agassiz, 1862.

Psephodus, sp. nov.

Among the fish remains from Summit there is a series of three lower (?) dental plates of *Psephodus*, having the following characters, viz.:—The plates increase in size from before backwards, and have the following measurements: anterior plate, anterior posterior measurement 0·0008 m., transverse 0·0015 m.; median plate, anterior posterior 0·001 m., transverse 0·002 m.; posterior plate, anterior posterior 0·001 m., transverse 0·0025 m. The margins, where the teeth are in juxtaposition, are nearly straight, the anterior one being very slightly convex, whilst the posterior one is very slightly concave; the posterior margin is greater in transverse measurement than the anterior; the outer margin is straight, the inner one gently curved throughout its length. The crown is gently arched from side to side, and the anterior external angle being somewhat inrolled gives a slight obliquity to the coronal ridge. The crown is covered with a dense layer of ganoine. The base is thick and strong, and conforms with the surface of the crown.

Remarks.—Although the plates are so small, their characters are so well displayed that I am not inclined to consider them as plates of a young fish, but rather, from the fact that they do not appear to agree with the specific diagnosis of any of the known species of *Psephodus*, I am inclined to treat them as dental plates of a new species, for which, on account of their small size, I propose the specific designation *minuta*.

Form. and loc.: D Shales, Middle Grits, at Summit.

Genus PŒCILODUS, McCoy (*ex* Agassiz), 1855, amend. A. S. W., 1889.

Pœcilodus Jonesii, McCoy, 1855.

Anterior half of a dental plate.

Form. and loc.: D Shales, Middle Grits, Summit.

Family CESTRACIONTIDÆ.

Genus ORODUS, Agassiz, 1838.

Orodus elongatus, Davis, 1883.

I have found two well-marked teeth of this species, one being almost identical with *O. elongatus*, the other with *O. angustus*, as figured by the late Mr. J. W. Davis, F.G.S.[2]

Form. and loc.: D Shales, Middle Grits, Summit.

[1] Wellburn, op. cit. [2] Trans. Roy. Dublin Soc., vol. i, sect. 2, pl. li, figs. 1, 4.

Insertæ sedis.

I here place certain small Helodont teeth, one of which shows the characters of *H. triangularis*, Davis, the latter, from its unsymmetrical form, being in all probability a medio-lateral, and others, which are smaller and more symmetrical, being symphyseal teeth of *Psephodus* or some other Cochliodont fish.

Form. and loc.: D Shales, Middle Grits, Summit.

Family ACANTHODIDÆ.

Genus ACANTHODES, Agassiz, 1833.

Acanthodes Wardi, Egerton, 1866.

The best specimen of this fish I found at Summit; it shows the fish from a point a short distance in front of the pectoral fin spine, the basal portions of which are preserved, to a point some little distance behind the dorsal fin spine, which is also present. The body is clothed with small quadrate scales, which I am unable to distinguish from those of *A. Wardi*, Egert., of the Coal-measures. Besides the above, fragments of the fish and many fin spines have been found.

Form. and loc.: D Shales, Middle Grits, Summit; Boulder Clough, Sowerby; and Kilne House Wood, Luddenden, near Halifax.

Acanthodes, sp. nov.

One fragment of *Acanthodes* shows characters which appear to entitle it to specific distinction, viz., the scales are very minute and are ornamented with fine diagonal striæ. The only species of *Acanthodes* that I know of with this scale sculpture is *A. concinnus*, Whiteaves,[1] but in this species the fin spines are ornamented with "about four longitudinal grooves," whereas the present species shows no evidence of these grooves, the fin spines being broad and elongated, having a single groove and ridge running parallel with the anterior border. On account of the scale sculpture I propose the specific designation *striatus* for this species.

Form. and loc.: D Shales, Middle Grits, Summit.

Genus CLIMATIUS, Agassiz, 1845.

Climatius, sp. ?

Among the fish remains there is the crushed body of a small Acanthodian fish of about 50 mm. in length. The body, which appears to have been of a somewhat slender form, is covered with smooth quadrate scales, and there are several fin spines present, some being detached from the body but lying in close proximity to it; the majority of the spines are broad and robust, the others being straight, narrower, and more elongated, and all are ornamented with coarse longitudinal ridges, and in general characters agree very closely with those of the Old Red Sandstone fish *Climatius* as figured and described by Sir P. Egerton[2] and Mr. J. Powrie, F.G.S.[3] I have also carefully examined the specimens of *Climatius* in the

[1] Trans. Roy. Soc. Canada, vol. vi, sect. 4.
[2] Mem. Geol. Survey, Fig. and descrip. organic remains, dec. x.
[3] Trans. Edin. Geol. Soc., vol. i.

British Museum (Natural History), Cromwell Road, and consider that the above fish should be placed in this genus, but the crushed condition of the specimen renders the determination of its species one of some difficulty, and it appears best to leave this question for later consideration. Besides the above I have found several detached spines of this fish.

Form. and loc.: D Shales, Middle Grits, Summit.

ICHTHYODORULITES.

Genus ACONDYLACANTHUS, St. John & Worthen, 1875.

Acondylacanthus, sp.?

One spine shows the characters of this genus, but it has suffered so much from erosion that the determination of its species is impossible.

Form. and loc.: D Shales, Middle Grits, Summit.

Genus EUCTENODOPSIS, gen. nov.

Euctenodopsis, sp. nov.

This Ichthyodorulite is most interesting, and at first sight might easily be mistaken for a specimen of the nearly allied genus *Euctenius*, Traquair. However, on a more careful examination it is at once apparent that it does not agree with the generic diagnosis of that genus, as given by Dr. Traquair,[1] in the important fact that, instead of having one end (the proximal) "rounded or blunt," this portion is drawn out and forms a more or less spatulate extension, which appears to differ somewhat in texture from that of the other portions of the spine. I say spine, as I consider the Ichthyolite was a dermal defence of some Selachian fish, and that the spatulate extension was its point of insertion. Although the spine is narrower and more elongated than any of the known species of *Euctenius*, still, in many of its characters it agrees with that genus, being more or less elliptical in form, laterally compressed, one side concave, the other convex, one extremity produced into a long narrow extension, and the convex margin is divided in a comb-like manner into a number of closely arranged blunt-pointed denticles.

On account of the above-mentioned peculiarity—the spatulate extension at its proximal end—I venture to place the spine in a new genus, for which I propose the name *Euctenodopsis*, and, on account of its narrow and elongated form, with the specific designation *tenuis*.

Form. and loc.: D Shales, Middle Grits, Summit.

Family RHIZODONTIDÆ.

Genus STREPSODUS, Young, 1866.

Strepsodus sulcidens, Hancock & Atthey, 1870–1871.

Mr. Aitken[2] in his paper refers to a tooth of *Strepsodus*. Mr. John Ward, F.G.S., of Longton, who has seen the specimen, informs me that it was a tooth of *Strepsodus sulcidens*.

Form. and loc.: D Shales, Middle Grits, Wadsworth Moor.

[1] Geol. Mag., Dec. II, Vol. VIII (1881), pp. 36–334.
[2] Aitken, *op. cit.*

Family CŒLACANTHIDÆ.

Genus CŒLACANTHUS, Agassiz, 1836, 1843.

Cœlacanthus, sp. nov. ?

I have found several slabs showing the remains of this genus, but am as yet not satisfied as to the species, although I am inclined to regard it as new on account of the proportion and ornamentation of the head bones and the sculpture of the scales.

Form. and loc.: D Shales, Middle Grits, Summit.

Family PALÆONISCIDÆ.

Genus RHADINICHTHYS, Traquair, 1877.

Rhadinichthys, sp. nov.

Form. and loc.: D Shales, Middle Grits, Summit.

Rhadinichthys, sp. nov. ?

Form. and loc.: D Shales, Middle Grits, Summit.

Genus ELONICHTHYS, Giebel, 1848.

Elonichthys Aitkeni, Traq., 1886.

Several fragments of this fish have been found.

Form. and loc.: D Shales, Middle Grits at Summit and Wadsworth Moor [1] (also B and C Shales, Middle Grits and the Rough Rock, localities not given [2]).

Elonichthys, sp. nov.

Form. and loc.: D Shales, Middle Grits, Summit.

Elonichthys, sp. nov.

Form. and loc.: D Shales, Middle Grits, Summit.

Genus ACROLEPIS, Agassiz, 1833, 1844.

Acrolepis Hopkinsi, McCoy, 1855.

Several fine fragmentary specimens of this fish have been found, notably those from Wadsworth Moor which are in the Woodwardian Museum, Cambridge.[3]

Form. and loc.: D Shales, Middle Grits at Summit and Wadsworth Moor.

Note.—I intend to fully describe the new species later. Mr. John Ward, F.G.S., who has seen the specimens, quite agrees with me that they are undoubtedly new. The fish remains, with two or three exceptions, are in the author's cabinets.

Before concluding, I must acknowledge, with warmest thanks, the great obligation I am under to Dr. Henry Woodward, F.R.S., etc., and Dr. A. Smith Woodward, F.L.S., for allowing me to examine and compare my fish remains with those in the Natural History Museum, Cromwell Road. I am also indebted to Mr. John Ward, F.G.S., for giving me his opinion on the new Palæoniscidæ.

[1] Wellburn, op. cit.
[2] Spencer, op. cit.
[3] Wellburn, op. cit.

TABLE OF LOCALITY AND STRATIGRAPHICAL DISTRIBUTION.

	D Shales, Middle Grits, Summit, Lancashire.[1]	D Shales, Middle Grits, Wadsworth Moor, Yorkshire.	D Shales, Middle Grits, Boulder Clough, Sowerby, Yorkshire.	D Shales, Middle Grits, Kilne House Wood, Luddenham, near Halifax, Yorks.	D Shales, Middle Grits, Eccup, near Leeds, Yorkshire.	B Shales, Middle Grits. Locality ?[2]	C Shales, Middle Grits. Locality ?[2]	Rough Rock. Locality ?[2]
Subclass Elasmobranchii.								
Order Ichthyotomi.								
Cladodus mirabilis, Agassiz	?	*						
Order Selachii.								
Pristodus falcatus, Davis...	*							
Psephodus, sp. nov.	*							
Pœcilodus Jonesii, McCoy	*							
Orodus elongatus, Davis	*							
Helodus, sp. ?	*							
Order Acanthodi.								
Acanthodes Wardi, Egerton	*	*	*	*	*			
Acanthodes, sp. nov.	*							
Climatius, sp. ?	*							
Ichthyodorulites.								
Acondylacanthus, sp. ?	*							
Euctenodopsis, gen. et sp. nov.	*							
Subclass Teleostomi.								
Order Crossopterygii.								
Strepsodus sulcidens, Hancock & Atthey	...	*						
Cœlacanthus, sp. nov. ?	*							
Order Actinopterygii.								
Rhadinichthys, sp. nov.	*							
Rhadinichthys, sp. nov. ?...	*							
Elonichthys Aitkeni, Traquair	*	*	...	...	...	*	*	*
Elonichthys, sp. nov.	*							
Elonichthys, sp. nov.	*							
Acrolepis Hopkinsi, McCoy	*	*	...	...	*			

* New to the Millstone Grit rocks.

[1] This is the first time that fish remains have been described from this locality.

VII.—Oscillations in the Sea-level. (Part II.)

By H. W. Pearson.

(*Continued from the April Number, p.* 174.)

IN the "Gallery of Nature," Milner, p. 388, it is stated that Brighton (then a mere village) in the time of Elizabeth (1558–1603) "stood upon a site where the sea now rolls, and where the chain pier stands." We might infer from this statement that at Brighton the sea, since the date mentioned, had been elevated over the land. We cannot draw this conclusion, however, with certainty, for the reasons following:—

During the last century the eastern coast of England has been constantly eaten into by the sea; churches, farms, and towers have been repeatedly devoured by the waves. In this district, however, we know that these results have not been caused by a rise in surface-level of the waters; we know that erosion by waves and currents has been the sole cause for these changes. It is absurd, therefore, to assume that Brighton during the last few centuries has alone suffered submergence, while all Britain has elsewhere undergone continual upheaval. Erosion, then, is the more probable explanation of this item, and it should not be held as evidence conflicting with our curve.

A conflicting point of great weight was found in Rear-Admiral Smyth's statement, that the city of Spina in the time of Scylax "was about $2\frac{1}{2}$ miles from the sea, but in less than 600 years afterwards Strabo describes it as being 90 stadia, or more than eleven miles inland" ("The Mediterranean," p. 47). This remark of Smyth's as to the 600 years disturbed me. Our period of vibration in the sea-level at the time mentioned being perhaps a little short of 600 years, there should have been little change in Spina's distance from the sea at these two epochs. On investigation, however, I found that there were two or three writers of this name. I believe, therefore, that Smyth, like others before him, has confounded Scylax of Caryanda, author of the "Periplus" of the Mediterranean, who wrote about 335 B.C. (Müller) or 352 B.C. (Niebuhr), with the Scylax of Caryanda who explored the Indus for Darius perhaps 515 B.C. or a little later. (See Encyc. Brit., article *Scylax*.)

It seems much more probable to me that information as to the shores of the Adriatic should be found in the writings of the later Scylax. I therefore, with some reason, assume that in this case I am more liable to find *two points confirmatory of my curve*, one for the low-water period of the epoch of Strabo, the other for the high-water period of the later Scylax, rather than a conflicting point as it first appeared on my diagram.

Strabo (Bk. xvi, chap. 4) describes the harbour of Charmothas, Arabia, as, at the time of his writing, apparently in actual existence. Under the same chapter, however, in a footnote from Gossellin, we learn that to-day, from the accumulation of soil, this harbour "is more than a day's journey into the interior of the country." This recession should not be; no retreat of the sea, if our curve is to

[1] This is the first time that fish remains have been described from this locality.
[2] These three horizons given on the authority of the late Mr. James Spencer, of Halifax (*op. cit.*).

be depended on, can have occurred since Strabo's epoch; this observation is therefore strongly antagonistic to our conclusions.

On investigation, however, we learn that Strabo's statement was borrowed from Artemidorus, who in his turn had borrowed his description from Agatharchides, 146 B.C. or thereabouts. We find, when we thus trace the observation to its true date, that all antagonism disappears. Agatharchides flourished during a high-water period, consequently the observed recession could have been foretold from inspection of our curve. (For discussion of true date see Hamilton & Falconer's Translation, vol. iii, p. 192.)

On theoretical grounds, the high sea-level culminating about 250 B.C. may, it seems to me, need moving back perhaps 50 years or thereabouts. This idea is derived from the following considerations :—

Our curve was drawn centrally through the preponderating masses of dots. Now it is well known that information such as used in this work becomes more and more scanty as we go backwards in time. While much evidence exists between the era of Augustus and the fall of the Western Roman Empire, 476 A.D., it rapidly decreases as we pass to the period before Cæsar; therefore we must anticipate that our observed points will be relatively greater in number for the same high sea-level as we approach from 250 B.C. to the time of Christ. The greater accumulation of points at the later dates consequently has probably brought the apex of our curve somewhat too near the time of the Christian era. How much distortion there may be found properly due to this cause further research may determine.

If later investigation shall allow this shifting of the curve at the epoch 250 B.C. as suggested, it would result in removing one more of our conflicting points, viz., that Reclus tells us at the time of the Battle of Thermopylæ (480 B.C.) the sea extended much farther into the land than now. The curve as now drawn would show the sea-level at the date of battle but slightly above the present level; this shifting would increase considerably its altitude at that time, and would better satisfy the requirements of Reclus' remark.

A few points I am at present unable to explain: for instance, Rear-Admiral Smyth calls attention to certain ruins near the town of Nettuno, Italy, "among which is Astura, so long the residence of Cicero . . . . now submerged in the sea." During the later years of Cicero (106–43 B.C.) our curve calls for a sea-level differing but little from the present; a sea-level, in fact, slightly above that of to-day. No building, therefore, then above the sea should be now submerged. I feel confident that some mistake will eventually be found in this statement. It may be that the residence of Cicero has not been identified with certainty, or it may be that near Nettuno, as in the Bay of Baie, foundations of buildings were erected in the sea. At present however, this item remains a conflicting point, antagonistic to our curve. I have no item more unyielding than this.

The above analysis illustrates the character of the examination bestowed on the testimony found conflicting with our curve. Lack

of space now forbids a more complete discussion of this matter. I will say, however, that a recent canvass of over 500 manuscript pages of these changes demonstrates that the conflicting points, accumulated during many years of continuous search, aggregate less than 4 per cent. of the total items collected. Over 96 per cent. of the testimony thus indiscriminately gathered falls into harmony with our curve.

It seems impossible that the extraordinary method appearing in this matter should be the result of chance. I believe firmly, therefore, that law prevails in these oscillations, and while this preliminary examination has as yet not been carried far enough to establish this position, it renders our conclusions most extremely probable. When this work was first entered upon, some years since, I had little knowledge of what had been done before me in this field, but I soon found much had been done; I am far from being the first to announce "Oscillations in the Sea-level."

Aristotle (384–322 B.C.) had suspected them; he stated "there is reason for thinking that these changes (replacement of land by sea, and *vice versâ*) take place according to a certain system and within a certain period" ("Principles," 9th ed., p. 13).

Ovid (43 B.C. to 17 A.D.) makes Pythagoras say in regard to these oscillations—

> "The face of places and their forms decay,
> And that is solid earth which once was sea:
> Seas in their turn retreating from the shore,
> Make solid land what Ocean was before;
> . . . . . .
> Antissa, Pharos, Tyre, in seas were pent,
> Once isles, but now increase the continent;
> While the Leucadian coast, mainland before,
> By rushing seas is severed from the shore,
> And men once walked where ships at anchor ride,
> Till Neptune overlooked the narrow way,
> And in disdain poured in the conquering sea."
>
> *Metamorphoses*, Bk. xv, Addison's translation.

Ovid has introduced here events that occurred both before and after the time of Pythagoras (580 to 500 B.C.). They all bear testimony, however, to the ever recurring nature of these changes, even if the dates and order of sequence be somewhat confused. (See "Popular History of Science," Routledge, p. 17.)

Sir Charles Lyell ("Principles," 9th ed., p. 526) had reason to suspect that the upheaval of Scandinavia, in progress at the time of his visit, had not always proceeded at the same rate, and that the motion had not been invariably in one direction. He says: "Some phenomena in the neighbourhood of Stockholm appear to me only explicable on the supposition of the alternate rising and sinking of the ground since the country was inhabited by man."

Mr. R. C. M. Brown has many times denied the doctrine of upheaval of coastline, and has urged change in absolute level of the sea from astronomical causes in its stead.[1]

[1] See Report Brit. Assoc. Ad. of Science, 1890, p. 824; Quart. Journ. Geol. Soc., vol. xlvi, p. 122.

Elisée Reclus, in "The Earth," discusses at length the subject of upheaval and depression of shore-lines; he shows the inability of sedimentary processes to account for the shoaling of the many ports of the Mediterranean or for the advance of the coastlines into the sea; he says, in these matters, "we are witnessing the phenomena of a vertical impulse" (p. 539); on p. 542 he shows us that this "vertical impulse" has affected the entire area of the Mediterranean. The study of these and similar upheavals and depressions over the earth's surface leads him to say: "As will be understood, these regular oscillations must take place in obedience to some general law still unknown, although none the less certain" (p. 566). We should note here, that while Reclus attributes these oscillations to movements of the earth, it is impossible to distinguish such movements from oscillations in the sea; the effect is precisely the same in either case.

Rear-Admiral Smyth seems to have noted these oscillations; he says: "It is decided, upon what appears to be sound geological evidence, that a great part of the Italian coast has been raised and lowered *several times* within the historical era, while the sea must have ever maintained the same level" ("The Mediterranean," p. 26). Again, on p. 28 he remarks: "It may be safely concluded that the land has *risen and fallen twice* since the Christian era, and that each movement of elevation and subsidence has exceeded twenty feet."

Mr. P. Thompson, in "The History and Antiquities of Boston," has shown that these same oscillations have occurred in the Fens of England. On p. 660 he demonstrates these changes to have been four in number since the time of the Romans, two periods of inundation and two periods of desiccation, but these periods can also be determined from the data attached to this argument. Oscillations of the sea-level have also been shown at Rye and Winchelsea and in the English Channel, the latter by Peacock.

We note, however, that the above quoted authorities, although they may have suspected these oscillations, or may have actually observed them, have in no case attempted to control these phenomena by law or to determine the period of vibration. Law has been invoked, however, by Professor Edouard Suess and by Trautschold, a quotation from this latter having been previously given, notwithstanding the "resolve to abandon the doctrine of secular oscillations of continents" (Suess), and the adoption of periodic fluctuations in the sea-level in its stead. I am unable to learn that either of these gentlemen has attempted determination of the period of these fluctuations; it may therefore be possible that this is the first attempt in that direction.

I show no curve beyond the 400 B.C. At this period the evidence which I have been able to collect becomes uncertain, scanty, and the dates are very unreliable. The Deucalion Deluge, the Ogygian Deluge, and the Deluge of Samothrace furnish data at remote and uncertain periods. The books of Homer, of Herodotus, of Strabo, of Ptolemy, and other ancient writers supply much information as to the position of the sea-level at periods from 600 to 200 B.C.; but

owing to the habit those ancient writers had of describing a city, an island, a peninsula, or a coastline, in terms borrowed from some still earlier and more ancient writer, it is at times difficult to decide as to the particular date at which the description fitted the object. The testimony so gathered is therefore very conflicting in its nature. I believe, however, that we find the amplitude of vertical vibration in the waters very much greater at that time than now, and the period of change reduced to approximately 500 years.

It is evident from what has gone before, that these oscillations have had a continuous existence for the last 2,400 years. In this paper we show strong evidence that these phenomena are periodic in their nature, and that the periods of these cycles are capable of determination. It is also equally evident, if any weight be attached to the facts herein contained, that the whole Northern Hemisphere, during the last three hundred years or more, has been subject to a general protrusion above the level of the sea.

Let us now consider, then, those evidences as to present opposing movement of shore-lines, to which attention has already been called; movements which, at the first glance, seem to deny so positively the conclusions arrived at in the above discussion.

To open the argument, I believe we maintain with great reason, that if there has been a bodily transference during the last few centuries, of a considerable mass of water from the Northern Hemisphere to the Southern, there must, coexistent with this transfer, have been considerable *decrease* in flow of currents running to the north and corresponding *increase* in currents flowing to the south.

Now then, acting on this assumption, the writer has shown in the *American Geologist* for September, 1899, perfect explanation of these apparently irregular motions; it is there shown that every observed case of apparent upheaval on one coastline, coincident with subsidence on another, can be foretold by law, and that instead of these motions being opposed to our conclusions, they are directly confirmatory thereof, it being demonstrated that no transference of water to the south can occur, no upheaval of northern shore-lines can take place, without a corresponding subsidence on the coasts of the Eastern United States, and also on the borders of such other lands as may be similarly situated with regard to ocean currents.

I will not repeat all the arguments used in the paper mentioned, but will state that our case hinges on the law of deformation of ocean levels by ocean currents, as announced by William Ferrell in *Science*, vol. vii. He says: "In the North Atlantic the tendency to flow eastward in the middle and higher latitudes causes a slight heaping up of the water and a rise of surface-level adjacent to the coast of Europe, and a drawing away of the water and a depression of sea-level along the north-east coast of the United States" (p. 76).

I have shown in the periodical mentioned that the waters around the British Islands and on the Scandinavian shores are

now piled, certainly 5 feet (probably much more on the coast of Norway) above the normal sea-level, and that the waters on the eastern borders of the United States are correspondingly depressed. It follows, therefore, that if the Gulf Stream—that force which now restrains these waters in their abnormal position—should decrease but slightly in its velocity of flow, the oceanic surface would at once return in part towards that normal level from which it has so long been displaced; in other words, Scandinavia and the British Islands would enter upon an epoch of upheaval, the Carolinas upon an epoch of subsidence. As we have seen, the recent protrusions of the north renders certain the fact that a great mass of water has recently disappeared from this hemisphere. The transfer of this water to the south makes an equal certainty that coexistent with this removal all northward-flowing currents should have decreased in their velocity of flow. It is clear, therefore, that these opposing motions in our coastlines can be reduced to law and foretold in advance of observation.

We have reason to believe, however, that apparent upheavals or subsidences due to this cause will not at any time exceed 2 or 3 feet in vertical movement, and they consequently are of little importance as compared with the periodic vibrations of 15 or 20 feet over an entire hemisphere, as developed herein. It nevertheless is important to detect and eliminate these minor deviations, when we attempt the general investigation of coastal phenomena. For a more extended, although still very incomplete discussion of Ferrell's law, see the *American Geologist*, as before mentioned.

To those who may wish to extend these investigations—and there is great opportunity for such extension—caution should be given against relying on evidence as to changes in the sea-level gathered near the mouths of great rivers or in deltas like those of the Nile, Po, Rhone, Rhine, Mississippi, etc. These delta deposits, independent of their surroundings, are all sinking bodily and spreading laterally, probably under some process of disgorgement of their water contents. Much evidence of this exists. For instance, E. L. Corthell says the delta lands of the Mississippi are unstable both in vertical and lateral direction. A base-line 700 feet long, measured accurately, had in five years increased to 712 feet. He also quotes from the Report of the Mississippi River Commission: "Discrepancies in beach marks, level heights, and gauges could only be satisfactorily accounted for by the most plausible explanation of the subsidence of the whole delta" (*The National Geographic Magazine*, December, 1897).

M. Staring is of the opinion that the gradual depression of Holland "is caused only by the subsidence of the alluvial ground, the weight of the dikes, and the incessant passage of men and cattle" (Reclus, "The Earth," p. 547). Regions like the northern and western shores of the Adriatic, the deltas of the Rhine and Mississippi, should thus be avoided; the settlement of these delta deposits may obliterate the vertical movements in the aqueous envelope: observations made along rock-bound coasts only are trustworthy.

From the argument preceding it seems necessary to conclude that in future study of changes in the sea-level, discrimination must be made between each of the following causes which may affect the oceanic borders :—

1. Seek the effects produced by the bodily transference of water to and from the north. These effects would be *universal* over *one hemisphere.*

2. Detect and eliminate those movements of upheaval or depression due to variation in flow of ocean currents under the operation of Ferrell's law. These effects are local in their nature.

3. In deltas always suspect that any observed depression may be due to a local settlement of the ground itself, and such data there gathered may offer no argument whatever in favour of a rise in sea-level.

4. Eliminate and avoid such coastal changes as may be due to erosion of or accretion to shore-lines. In changes of this century it is generally possible to do this. In changes that have occurred in the distant past we shall find much difficulty in separating results of erosion or accretion from the results of real changes in the sea-level; therefore, in past ages much testimony will be found accumulated against us which our analysis will be unable to remove; we must expect, therefore, many of these apparently conflicting observations.

All the evidence discussed hereto has been gathered on the oceanic coastlines; these data, as we have seen, testify to a recent protrusion of the entire north, and that this apparent vertical uplift increased in amount as we approach the Pole. There is, however, evidence in existence, obtained from our great lakes, showing the same law of greater elevation to the north.

Mr. G. K. Gilbert, in the 18th Ann. Rep. U.S. Geol. Survey, has shown that this excess of upheaval at the north has been of recent occurrence in the interior of our continent. A careful study of the changes in level, during the present century, of the great lakes enables Gilbert to announce this law with certainty.

With his inferential conclusions, however, in the light of our own investigation, we are compelled to differ. He assumes that this motion may continue indefinitely, and if so, he shows that in time the Niagara Falls will cease their flow, and a new outlet to the great lakes be placed in operation near Chicago. This result he reaches in a logical manner from the data examined, but we see that observations reaching back only one hundred years allow us to form no certain opinion as to whether this motion will continue indefinitely in one direction or otherwise. Then, again, the area of investigation was of too limited a character. We have seen that to obtain the law governing these risings and sinkings, it is not only necessary to study at one field of view the entire Northern Hemisphere, but to carry our investigation back in time as far as history or tradition will allow. When this has been done we see that Gilbert's observed changes in level fall into line as part and parcel of one complete system, universal over the entire North.

The cause of this vibration in the oceanic waters it is perhaps too early to discuss; the oscillations should be first established beyond a doubt. The most plausible explanation of the last change, however, would seem to rest in a possible continued *increase* in growth of the South Polar glaciers during the last few centuries, contemporaneous with that general *decrease* in nearly all Northern glaciers which, during the period mentioned, we know has been in progress. If we could invoke this cause, the recent oscillation mentioned would then be a physical necessity.

The question raised in this paper, and the results that have been reached, seem to warrant certain inferences or speculations, some of which are liable to be of considerable importance. For instance, we know that the landing-place of Columbus in 1492 has not yet been positively identified; our curve, however, calls for a sea-level at that latitude and date some 12 to 15 feet higher than at present. The question is, would the change in topography produced by assuming the sea at its old position aid us in reaching final conclusion in this matter.

As our curve for time past indicates a series of regular cycles with a period of about 640 years, must we not suppose our oceanic surface will again rise in the north, reaching its maximum shortly after the year 2100. If we prolong this curve, as suggested, we must conclude that disaster, as repeatedly in the past, will soon again overwhelm our northern coastlines. Are such cities as London, Liverpool, and New York ready for this advancing sea, and has such a region as Holland any too much time for preparation?

If our curve has been correctly mapped out, we must suppose that the northerly movement of the waters has already commenced, or that it will very shortly appear. This movement should be first shown in cessation of the so-called upheaval of Scandinavia, and that region should soon appear to be undergoing subsidence, while, at the same time, the coasts of New Jersey will enter an epoch of upheaval. We might, with great propriety, be on the look out for these changes.

Lord Kelvin has shown us how one inch of water taken from the surface of the sea, and piled up as ice at the Pole, would appreciably affect the rotation of the earth; we can reasonably expect, therefore, that these oscillations to and fro from the Poles to the Equator of 15 or 20 feet, as our arguments and facts seem to require, should have considerable effect in altering the length of our day. In fact, in this discussion we may, and probably will, find confirmation of Newcomb's surmise, that the hitherto unexplainable irregularities in the moon's motions may be due to slight changes in the earth's axial rotation, which rotation perhaps "varies from time to time in an irregular manner" ("Popular Astronomy," p. 101).

We thus see that there are reasons, many and weighty, inducing us to pursue this investigation to greater extent. Notwithstanding the considerable attention given to the subject by this writer, a research involving the labour of many years, we are as yet merely on the threshold of the inquiry. Years could be devoted to the comparison

of ancient and modern maps and charts. A lifetime could be expended on the emerged and submerged ruins of Ostia, Carthage, Utica, the Piræus, Alexandria, the Bay of Baie, Tyre, Miletus, and other places too numerous to mention on the ancient elevated or depressed coastlines of the Mediterranean. This task is far beyond the capacity of an individual. Law, if once established in this matter, is of universal value and importance. The obscurity shrouding these emerged and submerged cities already seems less dark than before.

I earnestly hope, therefore, that some scientific body will undertake to assist in extending this investigation, thus enabling us to shed still additional light on these perplexing oscillations of the sea which we have been considering.

(*To be concluded in our next Number.*)

REVIEWS.

SUR LES FOUILLES DE 1899 DE DÉBRIS DE VERTÉBRÉS DANS LES DÉPÔTS PERMIENS DE LA RUSSIE DU NORD. Par V. AMALITZKY. pp. 25, with 5 plates. Exposé fait à l'Assemblée générale de la Soc. Imp. des naturalistes à St.-Pétersbourg, le 28 Décembre, 1899. (Varsovie, 1900.)

PROFESSOR AMALITZKY has for several years past been engaged in working out the structure and history of the fresh-water deposits of Palæozoic age in the northern governments of Russia, and in the present paper he treats of some general questions in connection with his investigations, and further gives a detailed account of some explorations in Upper Permian strata on the banks of the Little Dwina, which resulted in the discovery of numerous plant and animal remains of considerable interest from their close relationship to the flora and fauna of the Gondwana beds in India, the Karoo formation of South Africa, and deposits of corresponding age in Brazil and Australia. Some of the reptilian remains, moreover, present a close resemblance to the genera *Elginia* and *Gordonia* described by E. T. Newton from the Elgin sandstones.

The lowest fresh-water deposits recognized by Amalitzky in the north of Russia are red sandstones situated at Mount Andoma, on the east side of Lake Onega, and, more to the east, at Oust-Pinéga on the Northern Dwina. They contain lamellibranch shells belonging to the genera *Carbonicola, Anthracosia, Archanodonta,* etc., allied to the Anthracosidæ of the Russian Carboniferous. The beds are of Upper Devonian age, and may be ranked with the Old Red Sandstones of Scotland, the Kiltorkan beds of Ireland, and the Catskill formation of North America. The only fresh-water formations of Carboniferous age observed by the author are the sands of the Lower Carboniferous at Mount Patrova, in the Vytégra district, which have been shown by Inostrantsev to be a direct continuation of the Devonian sandstones of Andoma. Higher up in the geological series, exclusively *marine* deposits persist from the Lower Carboniferous sandstones with *Productus giganteus* in the

Vytégra district, and more eastward at Oust-Pinéga, from the Upper Carboniferous sandstones with *Spirifer mosquensis*, quite up to the Lower Permian. The Upper Permian deposits, on the other hand, shown on the banks of the lower part of the River Suchona and near the sources of the Little Dwina of the North, exhibit fresh-water characters very distinctly. They consist of nearly horizontal beds of marl with intercalated lenticular beds of sand and sandstone. For a long period these strata were considered to be destitute of fossils; none were found in them by Murchison, Keyserling, or Blasius, and they were neglected by the Russian geologists by reason of this reputed barrenness.

Professor Amalitzky has, however, demonstrated by his discoveries during the last four years that they contain a rich flora and fauna. Amongst the plant remains the most important are *Glossopteris indica*, *Gl. angustifolia*, (*Vertebraria*), *Gangamopteris major*, *Tæniopteris*, *Sphenopteris*, *Callipteris* cf. *conferta*, besides *Equisetum*, *Noeggerathiopsis*, and forms like *Schizoneureæ*. The fauna includes a number of fresh-water lamellibranchs, such as *Palæomutela Inostranzewi*, *P. Keyserlingi*, *P. Verneuili*, *Oligodon*, *Palæanodonta*, *Carbonicola*, *Anthracosia*, and *Anthracomya*; the Crustacean genera *Estheria* and *Cypris*, together with the plates and impressions of Ganoid fishes. Land animals are represented by amphibians approaching *Melanerpeton* and *Pachygonia*, and a great number of bones of theromorphian reptiles belonging to the Pareiasauria and Dicynodontia, amongst which *Pareiasaurus* and *Dicynodon* have been definitely determined, and also forms much resembling *Elginia* and *Gordonia*.

These discoveries have confirmed the opinion of the author as to the great resemblance from a palæontological point of view between the Continental fresh-water deposits of the Upper Permian and those of the Lower Karoo in Africa and of the Gondwana in India; and he is led to conclude that the compact continent which during the Permian epoch occupied Central and Southern Africa, India, Australia, Argentina, and part of Brazil extended as far as European Russia, and that the bond which united these countries was on one side the Continental deposits of Gondwana in India and on the other the similar deposits of Kouzniets in Siberia.

The explorations carried out by Professor Amalitzky during the Summer of 1899, which form the main subject of the present paper, were made at a spot on the steep right bank of the Upper Dwina of the North, near the village of Kotlas. For a distance of about ten kilometres the river bank is composed of Permian rocks overlain by beds of clay, with pebbles and large stones of crystalline rocks, of Post-Pliocene age. The Permian beds have a slight dip towards the N.N.E.; they consist of a series of marls of very uniform characters; the upper beds are of a reddish-brown tint, with a persistent layer of white siliceo-dolomitic limestone, in some places becoming dolomitic, in others a siliceous rock. These upper marls rest with a slight discordance on lower marls, also reddish-brown, and not dissimilar to the upper beds; a thickness of about

24 metres is exposed of the lower marls. At the line where these marls come together there is a series of remarkable lenticular beds of sand resting in trenches eroded in the lower marls and unconformably overlaid by the upper beds. Five of these lenticular sand beds are shown in section in the steep river banks in the course of the ten kilometres referred to. The particular bed excavated, situated at Sokolki, was 12 metres thick in its central portion, with a breadth of about 80 metres. The bed contained numerous irregular, hard concretions of sand cemented with carbonate of lime, and in some of these the reptilian bones were enclosed. As the bank at this place was vertical, and the higher portions were even overhanging, the only practicable means of reaching the fossiliferous lenticular deposit was by digging down to it from above, which entailed much labour, and a further difficulty was caused by the fact that at a depth of 1·5 m. from the surface the soil, at the end of June, was frozen hard, and the small fissures and cavities were lined with ice.

Many impressions of large fronds of *Glossopteris* were met with in some of the sandy beds, but they broke up on exposure to the air. The position of the fossiliferous concretions was discovered only after several fruitless trials. Some of the concretions contained only single detached bones, whilst in others all the bones of a complete skeleton were embedded together. Three skeletons were found side by side, evidently of predatory animals allied to *Rhopalodon*; under these were three, more or less imperfect, skeletons of Pareiasauria. The sand surrounding the concretions was carefully removed and the surface of each layer exposed so that the positions of the skeletons could be distinguished. They appeared to be all extended in the same direction as if they had been carried down and deposited in the bed of a stream heavily charged with sediment. The skeletons in the central portions of the lenticular deposit were heaped together as if they had been buried up with silt before the flesh had decomposed, whilst those nearer the margins seem to have been exposed long enough for decay to have set in, so that the bones became detached.

No fewer than thirty-nine groups of concretions were discovered; about twenty of these contained complete or imperfect skeletons, whilst in the others the bones were detached and commingled together. These concretions have not as yet been properly examined, and their contents are but partially known. Of the remains of Amphibians, there are skulls and other bones of forms allied to *Melanerpeton* and *Metopias*.

Both in numbers and importance the reptilian remains form the chief part of the collection. They nearly all belong to the Theromorpha, and the three suborders, Anomodontia, Pareiasauria, and Deuterosauria, are represented. The Pareiasauria are the most abundant; amongst them are some small forms with skulls not more than 30 centimetres in length, whilst others are 4–5 metres long with skulls 1 m. in length and 0·66 m. in width. Some have their heads and part of their backs covered with shield-shaped plates, like

the Pareiasauria from the Karoo beds; others possess horn-like projections on their heads like the *Elginia* from the Triassic deposits of Scotland. All are characterized by the good preservation of their notched, spatula-shaped teeth. The Deuterosauria, though sometimes 3 metres in length, do not attain the proportions of the Pareiasauria. Their dental apparatus is very powerful and of a distinctly rapacious type. They belong to *Rhopalodon*, Fischer. The Anomodontia are represented by small forms of *Dicynodon* about the size of a bear, with two powerful tusks on the sides of the head. Some of the skulls and skeletons discovered probably belong to altogether new species of reptiles.

The only invertebrates mentioned from this lenticular deposit are lamellibranch shells belonging to the Anthracosidæ, whilst the plant remains, though numerous, are limited to forms of *Glossopteris*.

The plates accompanying the paper show the position of the lenticular sandy beds in the cliffs of Permian marls, and the manner in which the concretions with the bones embedded in them occurred in the sands. G. J. H.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—March 6th, 1901.—J. J. H. Teall, Esq., M.A., V.P.R.S., President, in the Chair.

The following communications were read:—

1. "Recent Geological Changes in Northern and Central Asia." By Professor George Frederick Wright, F.G.S.A.

The present paper is the outcome of a journey made by the author in company with Mr. Frederick B. Wright in 1900–1901.

In North America an area of about 4,000,000 square miles was brought under the direct influence of Glacial ice during the Glacial Epoch. The result of six weeks spent in Japan was to show that there are no signs of general glaciation in Nippon or Yesso. Neither is there any sign of glaciation along the border of the Mongolian Plateau, where the general elevation is 5,000 feet, but the whole region is covered with loess. This has usually accumulated like immense snow-drifts on the south-eastern or lee-side of the mountains, and in it houses and villages are excavated. In the mountainous region, strata of gravel and pebbles are so frequent in the loess, that it is necessary to invoke both wind and water in order to explain fully the origin of the deposit. At the present time the loess in the interior is being washed away by streams much faster than it is being deposited by the wind. The journey across Manchuria from Port Arthur along the Lao-Ho and Sungari rivers was through valleys choked with alluvium, and there was no evidence that the drainage of the Amur had ever been reversed by ice, like that of the St. Lawrence; nor was there any other evidence of glaciation. The lower course of the Amur indicates subsidence. Again, there are no signs of glaciation on the Vitim Plateau.

Lake Baikal appears to be of recent origin; it is 4,500 feet deep, and has not been filled by the great quantities of sediment brought down by the Selenga and other rivers. Although glaciers could frequently be seen on the mountains which border the Central Asiatic Plateau to the north-west, there was no evidence that the glaciers had ever deployed on the plain. The loess-region of Turkestan, and indeed the whole area from the Sea of Aral to the Black Sea, appears to have been recently elevated, in some places as much as 3,000 feet. Desiccation took place at the same time, so that the larger lakes are only brackish or still fresh. Direct evidence of this in the form of deposits is given. The author thinks it likely that the absence of glaciation in Northern Asia may have been due to the rainlessness of the region, and that while America was elevated, Asia was depressed during the Glacial Epoch.

2. "The Hollow Spherulites of the Yellowstone and Great Britain." By John Parkinson, Esq., F.G.S.

A recent journey to the National Park of the United States, resulting in a study of the obsidians and rhyolites in the field and at home, suggested a direct comparison between the hollow spherulites characteristic of these rocks and those of the rhyolites of Shropshire, Jersey, and elsewhere.

The first part of the paper is concerned with the spherulites of the Yellowstone region. A brief description is given (i) of the small bluish-grey solid spherulites common in the obsidian of Obsidian Cliff, and (ii) of a hollow variety in which radial structure is barely discernible. In the latter, the spherulitic part is represented by a whitish, rather crumbly material consisting of felspar, tridymite, and quartz.

The hollow spherulites proper are divided into two groups—(i) those containing cavities without definite form, and (ii) those in which the cavities are related to the shape and structure of the spherulite. The latter include the well-known lithophysæ. The manner in which these occur, and the relation of the cavities to the enclosing spherulite, are described. Attention is drawn (*a*) to the porous character of the latter, and (*b*) to the network of felspathic fibres, studded with crystals of tridymite, which usually distinguish the spherulite near a cavity.

Hypotheses framed to account for these varying structures would take one of two directions:—(i) Hollow spherulites are the result of some property of the original magma, or (ii) are due to the decomposition of an originally solid spherulite by heated waters. Taking the second alternative first, a description is given of the effect of solfataric action on the rhyolites of the Yellowstone Cañon. The conclusion reached is "that the action of hot waters charged with silica may be to remove portions of the rock, or to permeate it without destroying its characteristic structure; that we obtain, however, no evidence to show that the spherulites are most easily attacked, but rather the reverse." Explanation, therefore, is most naturally sought in some property of the original magma, and that propounded by Professor Iddings appears the nearest in accord with

facts. Exception is taken to certain physical processes postulated by Professor Iddings in a recent memoir, but with his earlier work the present writer is substantially in agreement.

In the second part of the paper direct comparison is drawn between the structures exhibited by the hollow spherulites from Obsidian Cliff and those of examples from Shropshire, Jersey, and other localities. Attention is called to the presence in the latter of quartzose amygdaloids, crescentic in shape, and having a relation to the edge of the nodule. Sometimes a series of such are found parallel one to the other, not infrequently (at Wrockwardine) becoming more or less completely circular. Projecting into such an amygdaloid, or occupying an end, we find in many instances a network of felspathic fibres comparable with the fibrous structure which characterizes the American examples.

A description is given of a series of rocks from Boulay Bay, once very vesicular, and containing the remains of crystals—probably felspars—analogous to the crystals found encrusting the cavities of lithophysæ from Obsidian Cliff. Traces of a mineral which resembles the tridymite from the latter locality are described from Wrockwardine.

Taking into consideration the resemblances between the hollow spherulites of the Yellowstone region and those of Great Britain, the conclusion is drawn that the hypothesis of corrosion is as inapplicable to the latter as to the former. On the contrary, the author believes that the cavities of the spherulites are the result of the hydrous state of the magma.

II.—March 20, 1901.—J. J. H. Teall, Esq., M.A., V.P.R.S., President, in the Chair.

Mr. H. B. Woodward called attention to a polished slab of Landscape Marble, or Cotham Stone, from the Rhætic Beds near Bristol, which had kindly been lent for exhibition by Mr. Frederick James, Curator of the Maidstone Museum. The specimen showed that after the arborescent markings had been produced in the soft mud, some irregular and partial solidification took place in the upper layers of the deposit; and then during contraction a kind of subsidence occurred of the upper and harder portions into the lower and softer materials. This subsidence was accompanied by a breaking up of the harder portions, suggesting a comparison (in miniature) with 'broken beds' and even crush-conglomerates. The specimen was of considerable interest as illustrating the mechanical changes produced during solidification.

The following communications were read:—

1. "On a Remarkable Volcanic Vent of Tertiary Age in the Island of Arran, enclosing Mesozoic Fossiliferous Rocks."

(Communicated by permission of the Director-General of H.M. Geological Survey.)

Part I.—"On the Geological Structure." By Benjamin Neeve Peach, Esq., F.R.S., L. & E., F.G.S., & William Gunn, Esq., F.G.S.

The rocks which form the subject of this paper cover an area of about 7 or 8 square miles, and culminate in Ard Bheinn A'Chruach

and Beinn Bhreac. They are in contact with formations ranging from the Lower Old Red Sandstone to the Trias, and are later in date even than the important faults of the area. They are made up partly of fragmental volcanic materials, and partly of various intrusive masses, confined within an almost unbroken ring of intrusive rocks. In addition to igneous fragments, the clastic volcanic rocks contain fragments derived from the surrounding formations; and also masses of shale, marl, limestone, and sandstone belonging to formations not now found *in situ* in the island. One of these is several acres in extent, contains fossils, and is in part of Rhætic age; a second is a fragment of Lias; and a third is of limestone and chert resembling the Antrim Cretaceous rocks, and yielding fossils. The absence of Oolitic and older Cretaceous seems to indicate a resemblance between a former succession in Arran and that now seen in Antrim. If these fragments fell into the vent from above, the igneous rocks must be of Post-Cretaceous age, and they give an impressive picture of the amount of denudation which has occurred since the period of vulcanicity.

Part II.—"Palæontological Notes." By E. T. Newton, Esq., F.R.S., F.L.S., F.G.S.

The masses of Rhætic strata yield *Avicula contorta*, *Pecten valoniensis*, *Schizodus* (*Axinus*) *cloacinus*, etc.; those of Lower Lias, *Gryphæa arcuata*, *Ammonites angulatus*, and new species of *Nuculana* and *Tancredia*, which are figured and described. Thin slices of the Cretaceous limestones prove to be very like those of the Antrim Chalk, and the rocks yield determinable Foraminifera, *Inocerami*, Sponges, and Echinoderms.

2. "On the character of the Upper Coal-measures of North Staffordshire, Denbighshire, South Staffordshire, and Nottinghamshire; and their Relation to the Productive Series." By Walcot Gibson, Esq., F.G.S.

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The Upper Coal-measures of North Staffordshire are capable of a fourfold subdivision, the groups representing a definite sequence of red and grey strata:—

4. The Keele Series. Red and purple sandstones and marl with occasional seams of coal, and bands of entomostracan limestone.
3. The Newcastle-under-Lyme Series. Grey sandstones and shales, with four thin seams of coal, and at the base an entomostracan limestone.
2. The Etruria Marl Series. Mottled red-and-purple marls and clays, with thin green grits; a thin coal occurs 150 yards above the base.
1. Black Band Series. Grey sandstones, marls, and clays; numerous thin seams of coal and Blackband ironstone; one of many thin bands of limestone is constant, 36 to 40 feet above the base.

Spirorbis- and entomostracan limestones attain a maximum in the Upper Coal-measures, but are not unknown in the productive measures below. Indeed, the two sets of measures are closely allied lithologically, palæontologically, and stratigraphically in this region. The chief movements are pre-Triassic and post-Carboniferous.

No attempt has been made to recognize the Black Band Series in

the Denbighshire, South Staffordshire, and Nottinghamshire coalfields, as they are indistinguishable from the productive measures in the absence of Blackband ironstones. In each of these areas there are divisions in the Upper Coal-measures which correspond with the three highest divisions in North Staffordshire, and in all cases, except near the margin of the basin, where overlap occurs, they are underlain by ordinary Coal-measures with coal-seams. It is therefore concluded that these higher Coal-measures were deposited in one basin which included all the four areas dealt with, and that whatever movements occurred were of a local, and not of a regional character. Judging by published descriptions, the higher series of measures appear to be present in other Midland and North-Western coalfields, and in most of them the Keele Series corresponds to the Salopian Permian of Professor Hull.

OBITUARY.

JOHN HOPWOOD BLAKE,

ASSOC. M. INST. C. E., F.G.S., OF THE GEOLOGICAL SURVEY OF ENGLAND AND WALES.

BORN JULY 22, 1843. DIED MARCH 5, 1901.

MR. J. H. BLAKE was a son of Mr. George John Blake, of the firm of Messrs. Allen & Blake, Wine Merchants, and was born in Great Tower Street in the city of London. After completing his education at King's College, London, he was apprenticed to Mr. R. P. Brereton, M. Inst. C. E., under whose directions he was engaged for several years with Mr. S. H. Yockney in railway work in Cornwall and South Wales. Having been attracted to the science of geology while at King's College, he became further interested in the subject during his engineering experiences, and was thereby tempted to join the Geological Survey in April, 1868, at a time when the staff under Murchison was considerably augmented. During the first few years of his official career he was engaged in the re-survey of portions of Somerset, along the Mendip and Polden Hills, at Shepton Mallet, Street, Chewton Mendip, and Axbridge, and subsequently at Watchet and Minehead. He was also occupied for a time in the first detailed Drift Survey of the area north-west of London. Later on he was transferred to Suffolk, to survey the country around Stowmarket, and that bordering the sea north and south of Lowestoft, whence he proceeded to Yarmouth and continued his investigations inland and along the coast as far north as Palling in Norfolk. Much time was then devoted to a careful study of the Forest Bed Series, and his published section of the cliffs at Kessingland, Pakefield, and Corton (1884) bears evidence of the painstaking character of his work. East Dereham then became his home, and much field-work was done in that part of Norfolk until 1884, when the primary one-inch Geological Survey of England was completed. Mr. Blake then removed to Reading, and was for many years occupied in the re-survey on the six-inch scale of that neighbourhood, giving

especial attention to the Drifts, which before had only been partially mapped. A few years ago he proceeded to Oxford, from which important and interesting centre he laboured with much quiet enthusiasm, until on March 5 he suddenly and quite unexpectedly succumbed to angina pectoris at the age of 57.

The record of his geological work is chiefly embodied in the geological maps of the districts he surveyed, and in sundry Survey memoirs. He contributed notes to the Geology of East Somerset (1876), to the Geology of Stowmarket (1881), the Geology of Norwich (1881), and the Geology of London (1889); and he personally wrote "The Geology of the Country around East Dereham" (1888) and "The Geology of the Country near Yarmouth and Lowestoft" (1890). He had also prepared, in conjunction with Mr. Whitaker, a Memoir on the Water Supply of Berkshire, which is in the press, and had made some progress with a Memoir on the Geology of Reading.

Mr. Blake's extra-official contributions to geological literature were by no means large considering his long experience. In 1872 he contributed (with H. B. Woodward) "Notes on the Relations of the Rhætic Beds to the Lower Lias and Keuper Formations in Somersetshire" (Geological Magazine, Vol. IX, pp. 196–202). In 1877 he published in the same Magazine (Dec. II, Vol. IV, pp. 298–300) an article "On the Age of the Mammalian Rootlet-bed at Kessingland"; and in 1881 he contributed to the Proceedings of the Norwich Geological Society (vol. i, pp. 126–128) a paper on a "Well-boring at East Dereham Waterworks." To these may be added his addresses to the Norwich Geological Society (of which he was elected President in 1880–81), dealing with the Age and Relation of the so-called 'Forest-Bed,' and with the Conservancy of Rivers, Prevention of Floods, Drainage, and Water Supply; and also his Presidential Address to the Reading Literary and Philosophical Society in 1885, when he discoursed on the Coalfields of the United Kingdom with special reference to the Royal Commission on Coal. From 1885 until near the close of his life he conducted a number of excursions of the Geologists' Association, on three occasions to Reading, and on other occasions to Henley-on-Thames and Nettlebed, Taplow and Bowsey Hill, Lowestoft and Kessingland, Goring, and Silchester, reports of which were contributed to the Proceedings of the Association.

Mr. Blake's early training as an engineer had made him an excellent draughtsman, so that his maps and the sections he constructed were models of neatness and precision. This training in the exact methods of topographic surveys to some extent hampered his field-work, as his constant aim to secure positive evidence for geological boundaries led often to prolonged and inexpedient investigation. Thus he would return again and again to obscure tracts in the hopes of gaining exact information, a process theoretically laudable, but practically detrimental to the progress of work. This timidity in forming conclusions, perhaps to a certain extent constitutional, had proved such a serious bar to official advancement,